1851

Ph. Ca... 1851
No 3.

THE

# COMPLETE WORKS

OF

# THOMAS DICK, LL.D.

CONTAINING

AN ESSAY ON THE IMPROVEMENT OF SOCIETY, THE PHILOSOPHY OF A FUTURE STATE, THE PHILOSOPHY OF RELIGION, THE CHRISTIAN PHILOSOPHER, MENTAL ILLUMINATION AND MORAL IMPROVEMENT OF MANKIND, AN ESSAY ON COVETOUSNESS, CELESTIAL SCENERY, SIDEREAL HEAVENS, AND THE PRACTICAL ASTRONOMER.

FIRST COMPLETE AMERICAN EDITION.

NINE VOLUMES IN THREE.

VOL. III.

HARTFORD:
PUBLISHED BY A. C. GOODMAN & CO.
1850.

# CELESTIAL SCENERY;

OR

## THE WONDERS

OF

## THE PLANETARY SYSTEM DISPLAYED;

ILLUSTRATING

## THE PERFECTIONS OF DEITY

AND A PLURALITY OF WORLDS.

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BY THOMAS DICK, LL. D.,

AUTHOR OF THE "CHRISTIAN PHILOSOPHER,"—"PHILOSOPHY OF RELIGION,"—"PHILOSOPHY OF A FUTURE STATE,"—"IMPROVEMENT OF SOCIETY BY THE DIFFUSION OF KNOWLEDGE,"—"THE MENTAL ILLUMINATION AND MORAL IMPROVEMENT OF MANKIND." etc. etc.

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# PREFACE.

The following work is intended for the instruction of general readers, to direct their attention to the study of the heavens, and to present to their view sublime objects of contemplation. With this view the author has avoided entering on the more abstruse and recondite portions of astronomical science, and confined his attention chiefly to the exhibition of *facts*, the foundation on which they rest, and the reasonings by which they are supported. All the prominent facts and discoveries connected with descriptive astronomy, in so far as they relate to the planetary system, are here recorded, and many of them exhibited in a new point of view; and several new facts and observations are detailed which have hitherto been either unnoticed or unrecorded.

The results of hundreds of tedious calculations have been introduced respecting the solid and superficial contents of the different planets, their satellites, and the rings of Saturn; their comparative magnitudes and motions, the extent of their orbits, the apparent magnitudes of bodies in their respective firmaments, and many other particulars not contained in books of astronomy, in order to produce in the minds of common readers definite conceptions of the magnitude and grandeur of the solar system. The mode of determining the distances and magnitudes of the celestial bodies is explained, and rendered as perspicuous and popular as the nature of the subject will admit; and the prominent arguments which demonstrate a plurality of worlds are considered in all their bearings, and illustrated in detail.

One new department of astronomical science, which has hitherto been overlooked, has been introduced into this volume, namely, *the scenery of the heavens as exhibited from the surfaces of the different planets and their satellites*, which forms an interesting object of contemplation, and, at the same time, a presumptive argument in favour of the doctrine of a plurality of worlds.

The author, having for many years past been a pretty constant observer of celestial phenomena, was under no necessity of adhering implicitly to the descriptions given by preceding writers, having had an opportunity of observing, through some of the best reflecting and achromatic telescopes, the greater part of the phenomena of the solar system which are here described.

Throughout the volume he has endeavoured to make the facts he describes bear upon the illustration of the Power, Wisdom, Benevolence, and the Moral Government of the Almighty, and to elevate the views of the reader to the contemplation of Him who sits on the throne of the universe, "by whom the worlds were framed," and who is the Source and Centre of all felicity.

In prosecuting the subject of Celestial Scenery, the author intends, in another volume, to carry forward his survey to the Starry Heavens and other objects connected with astronomy. That volume will embrace discussions relative to the number, distance, and arrangement of the stars; periodical and variable stars; new

and temporary stars; double and triple stars; binary systems; stellar and planetary nebulæ; the comets, and other particulars; accompanied with such reflections as the contemplation of such august objects may suggest. The subject of a plurality of worlds will likewise be prosecuted, and additional arguments, derived both from reason and Revelation, will be adduced in support of this position. The practical utility of astronomical studies, their connexion with religion, and the views they unfold of the perfections and the empire of the Creator, will also be the subject of consideration. And should the limits of a single volume permit, some hints may be given in relation to the *desiderata* in astronomy, and the means by which the progress of the science may be promoted, together with descriptions of the telescope, the equatorial, and other instruments, and the manner of using them for celestial investigation.

BROUGHTY FERRY, near DUNDEE,
*December*, 1837.

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# CELESTIAL SCENERY.

## INTRODUCTION.

Astronomy is that department of knowledge which has for its object to investigate the motions, the magnitudes, and distances of the heavenly bodies; the laws by which their movements are directed, and the ends they are intended to subserve in the fabric of the universe. This is a science which has in all ages engaged the attention of the poet, the philosopher, and the divine, and been the subject of their study and admiration. Kings have descended from their thrones to render it homage, and have sometimes enriched it with their labours; and humble shepherds, while watching their flocks by night, have beheld with rapture the blue vault of heaven, with its thousand shining orbs, moving in silent grandeur, till the morning star announced the approach of day. The study of this science must have been coeval with the existence of man; for there is no rational being who has for the first time lifted his eyes to the nocturnal sky, and beheld the moon walking in brightness amidst the planetary orbs and the host of stars, but must have been struck with admiration and wonder at the splendid scene, and excited to inquiries into the nature and destination of those far-distant orbs. Compared with the splendour, the amplitude, the august motions, and the ideas of infinity which the celestial vault presents, the most resplendent terrestrial scenes sink into inanity, and appear unworthy of being set in competition with the glories of the sky.

When, on a clear autumnal evening, after sunset, we take a serious and attentive view of the celestial canopy; when we behold the moon displaying her brilliant crescent in the western sky; the evening star gilding the shades of night; the planets moving in their several orbs; the stars, one after another, emerging from the blue ethereal, and gradually lighting up the firmament till it appear all over spangled with a brilliant assemblage of shining orbs; and particularly when we behold one cluster of stars gradually descending below the *western* horizon, and other clusters emerging from the *east*, and ascending, in unison, the canopy of heaven; when we contemplate the whole celestial vault, with all the shining orbs it contains, moving in silent grandeur, like one vast concave sphere, around this lower world and the place on which we stand—such a scene naturally leads a reflecting mind to such inquiries as these: Whence come those stars which are ascending from the east? Whither have those gone which have disappeared in the west? What becomes of the stars during the day which are seen in the night? Is the motion which appears in the celestial vault *real*, or does a motion in the earth itself cause this appearance? What are those immense numbers of shining orbs which appear in every part of the sky? Are they mere studs or tapers fixed in the arch of heaven, or are they bodies of immense size and splendour? Do they shine with borrowed light, or with their own native lustre? Are they placed only a few miles above the region of the clouds, or at immense distances, beyond the range of human comprehension? Can their distance be ascertained? Can their bulk be computed? By what laws are their motions regulated? and what purposes are they destined to subserve in the great plan of the universe? These, and similar questions, it is the great object of astronomy to resolve, in so far as the human mind has been enabled to prosecute the path of discovery.

For a long period, during the infancy of science, comparatively little was known of the heavenly bodies excepting their apparent motions and aspects. Instead of investigating with care their true motions, and relative distances and magnitudes, many of our ancestors looked up to the sky either with a brute unconscious gaze, or viewed the heavens as the book of fate, in which they might read their future fortunes, and learn, from the signs of the zodiac, and the conjunctions and other aspects of the planets, the temperaments and destinies of men and the fate of empires. And even to this day, in many countries, the fallacious art of prognosticating fortunes by the stars is one of the chief uses to which the science of the heavens is applied. In the ages to which I allude, the world in which we dwell was considered as the largest body

in the universe. It was supposed to be an immense plane, diversified with a few inequalities, and stretching in every direction to an indefinite extent. How the sun penetrated or surmounted this immense mass of matter every morning, and what became of him in the evening—whether, as the poets assert, he extinguished himself in the western ocean, and was again lighted up in the eastern sky in the morning—many of them could not determine. *Below* this mass of matter we call the earth, it was conceived that nothing but darkness and empty space, or the regions of Tartarus, could exist. The stars which gild the concave of the firmament *above* were considered only as so many bright studs fixed in a crystalline sphere, which carried them round every day to emit a few glimmering rays, and to adorn the ceiling of our terrestrial habitation. Above the visible firmament of heaven, and far beyond the ken of mortal eye, the Deity was supposed to have fixed his special residence, among myriads of superior intelligences. The happiness, the preservation, and the moral government of the human race were supposed to be the chief business and object of the Deity, to which all his decrees in eternity past, and all his arrangements in relation to eternity to come, had a special and almost exclusive reference. Such ideas are still to be found, even in the writings of Christian divines, at a period no further back than the sixteenth century.

To hazard the opinion that the plans of the Almighty embraced a much more extensive range—that other beings, analogous to men, inhabited the planetary or the starry orbs, and that such beings form by far the greater part of the population of the universe—would have been considered as a heresy in religion, and would probably have subjected some of those who embraced it to the anathemas of the church, as happened to Spigelius, bishop of Upsal, for defending the doctrine of the antipodes, and to Galileo, the philosopher of Tuscany, for asserting the motion of the earth. The ignorance, the intolerance, and the contracted views to which I allude, are, however, now, in a great measure, dissipated. The light of science has arisen, and shed its benign influence on the world. It has dispelled the darkness of former ages, extended our prospects of the grandeur and magnificence of the scene of creation, and, in conjunction with the discoveries of revelation, has opened new views of the perfections and moral government of the Almighty. In the progress of astronomical science, the distances and magnitudes of many of the celestial bodies began to be pretty nearly ascertained; and the invention of the *telescope* enabled the astronomer to extend his views into regions far beyond the limits of the unassisted eye, and to discover myriads of magnificent globes formerly hid in the unexplored regions of immensity. The planetary orbs were found to bear a certain resemblance to the earth, having spots and dark streaks of different shades upon their surfaces; and it was not long in being discovered that, notwithstanding their apparent brilliancy, they are, in reality, opaque globes, which derive all their light and lustre from the sun. The planet Venus, in different parts of its orbit, was observed to exhibit a gibbous phase, and the form of a crescent similar to the moon, plainly indicating that it is a dark globe, enlightened only on one side by the rays of the sun. The moon was perceived to be diversified with hills and valleys, caverns, rocks, and plains, and ranges of mountains of every shape, but arranged in a manner altogether different from what takes place in our sublunary sphere. The sun, which was generally supposed to be a ball of liquid fire, was found to be sometimes covered with large dark spots, some of them exceeding in size the whole surface of the terraqueous globe, and giving indications, by their frequent changes and disappearance, of vast operations being carried on upon the surface and in the interior of that magnificent luminary. Hundreds of stars were descried where scarcely one could be perceived by a common observer; and as the powers of the telescope were increased, thousands more were brought to view, extending in every direction, from the limits of unassisted vision throughout the boundless extent of space.

It is natural for an intelligent observer of the universe to inquire into the final causes of the various objects which exist around him. When he beholds the celestial regions filled with bodies of an immense size, arranged in beautiful and harmonious order, and performing their various revolutions with regularity and precision, the natural inquiry is, For what end has the Deity thus exerted his wisdom and omnipotence? What is the ultimate destination of those huge globes which appear in the spaces of the firmament? Are these vast masses of matter suspended in the vault of heaven merely to diversify the voids of infinite space, or to gratify a few hundreds of terrestrial astronomers in peeping at them through their glasses? Is the Almighty to be considered as taking pleasure in beholding a number of splendid lamps, hung up throughout the wilds of immensity, which have no relation to the accommodation and happiness of intelligent minds? Has he no end in view corresponding to the magnificence and grandeur of the means he has employed! Or, are we to conclude that his wisdom and goodness are no less conspicuously displayed than

his omnipotence in peopling those vast bodies with myriads of intelligent existences of various orders, to share in his beneficence and to adore his perfections? This last deduction is the only one which appears compatible with any rational ideas we can entertain of the wisdom and intelligence of the Eternal Mind, and the principles of the Divine government.

This opinion is now very generally entertained by those who have turned their attention to the subject. But it is frequently admitted on grounds that are too general and vague; on the authority of men of science, or on the mere ground that the planets and stars are bodies of immense size; and hence it is only considered as a *probable* opinion, and *a thorough conviction* of its truth is seldom produced in the mind.

In the following work it shall be our endeavour to show that the arguments which may be brought forward to establish the doctrine of a plurality of words have all the force of a *moral demonstration;* that they throw a lustre on the perfections of the Divinity; and that the opposite opinion is utterly inconsistent with every idea we ought to entertain of an Allwise and Omnipotent Intelligence.

In order to the full illustration of this subject, it will be necessary to take a pretty minute and comprehensive view of all the known facts in relation to the heavenly bodies; and while these facts will be made to bear upon the object now proposed, they will likewise tend to exhibit the scenery of the heavens, and to elucidate many of the prominent truths and principles connected with descriptive astronomy. In the progress of our discussions, we shall descend into many minute particulars which are generally overlooked by writers on the subject of astronomy, and shall introduce several original observations and views on this subject which have not hitherto been particularly detailed.

## CHAPTER I.

### *On the general appearance and apparent motions of the Starry Heavens.*

Before proceeding to a particular description of the real magnitudes, motions, and phenomena of the heavenly bodies, it may not be improper to take a brief survey of the general appearance and apparent motions of the celestial vault, as they present themselves to the eye of a common observer.

It is of importance to every one who wishes to acquire a clear idea of the principles of astronomy and the phenomena of the heavens, that he contemplate with his own eyes the *apparent* aspects and revolutions of the celestial bodies before he proceeds to an investigation of the *real* motions, phenomena, and arrangements which the discoveries of science have led us to deduce. From want of attention to this circumstance, there are thousands of smatterers in the science of astronomy who never acquire any clear or comprehensive ideas on this subject; and who, instead of clearly perceiving the relations of the heavenly orbs from their own observation, rely chiefly on the assertions of their instructors, or the vague descriptions to be found in elementary books. It is amazing how many intelligent men there are among us who would not wish to be considered altogether ignorant of modern astronomy, have never looked up to the celestial vault with fixed attention; have never made repeated observations to discover its phenomena; and cannot tell, from their own survey, what are the various motions it exhibits. There are thousands and ten thousands who have gazed on a clear evening sky, at certain intervals, during a period of many years, yet can tell no more about the glorious scene around them than that they behold a number of shining points twinkling in every direction in the canopy above. Whether these bodies shift their positions with regard to each other, or remain at the same relative distances; whether any of them appear in motion, while others appear at rest; whether the whole celestial canopy appears to stand still, or is carried round with some general motion; whether all the stars which are seen at six o'clock in the evening are also visible at twelve at midnight; whether the stars rise and set, as the sun and moon appear to do; whether they rise in the east, or north-east, or in any other quarter; whether some rise and set regularly, while others never descend below the horizon; whether any particular stars are occasionally moving backward or forward, and in what parts of the heavens they appear; whether there are stars in our sky in the daytime as well as well as during night; whether the same clusters of stars are to be seen in summer as in winter? To these and similar questions there are multitudes who have received a regular education, and who are members of a Christian church, who could give no satisfactory answers. And yet almost every one of these inquiries could be satisfactorily answered, in the course of a few evenings, by any man of common understanding who di-

rected his attention for a few hours to the subject, and that, too, without the knowledge of a single scientific principle. He has only to open his eyes, and to make a proper use of them; to fix his attention on the objects before him; to make one observation after another, and compare them together; and to consider that "the works of the Lord are *great*," and that they ought "to be sought out [or seriously investigated] by all those who have pleasure therein."

If this representation be admitted as just, what a striking idea does it present of the *apathy* and indifference of the greater part of mankind in regard to the most astonishing and magnificent display which the Creator has given of himself in his works! Had we an adequate conception of all the scenes of grandeur, and the displays of intelligence and omnipotent power, which a serious contemplation of a starry sky is calculated to convey, all the kingdoms of this world would sink into comparative insignificance, and all their pomp and splendour appear as empty as the bubbles of the deep. It is amazing that *Christians*, in particular, should, in so many instances, be found overlooking such striking displays of Divine perfection as the firmament opens to our view, as if the most august works of the Creator, and the most striking demonstration of his "eternal power and godhead," were unworthy of their regard; while we are commanded, in scripture, to "lift up our eyes on high, and consider Him who hath created these orbs, who bringeth forth their hosts by number," and who guides them in all their motions "by the greatness of his strength." "The heavens," says the psalmist, "declare the glory of the Lord, and the firmament showeth his handiwork." Though these luminaries "have no speech nor language," though "their voice is not heard" in articulate sounds, yet, as they move along in *silent* grandeur, they declare to every reflecting beholder that "the hand that made them is Divine."

One great cause of this indifference and inattention is to be found in the want of those habits of observation and reflection which ought to be formed in early life by the instructions imparted in the family circle and at public seminaries. Children, at a very early age, are endowed with the principle of curiosity, and manifest an eager desire to become acquainted with the properties and movements of the various objects which surround them; but their curiosity is, in most instances, improperly directed; they are seldom taught to make a right use of their senses; and when they make inquiries in reference to the appearances of nature, their curiosity is too frequently repressed, till, at length, habits of inattention and indifference take possession of their minds. A celebrated author represents his pupil as expressing himself in the following manner:—"I shall freely tell you the things which frequently occur to my mind, and often perplex my thoughts. I see the heavens over my head, and tread on the earth with my feet; but I am at a loss what to think of that *mighty concave* above me, or even of this very earth I walk upon. I often think whether the earth may not stretch out in breadth to immensity, so as, if one was to travel it over, one should never be able to get to the *end* of the earth, but always find room to continue the journey; nor can I satisfy myself as to the depth of the earth, whether it has any bottom; and, if so, what it can be that is below the earth. As to the heaven, I need say nothing: every change that happens, and every object seen there, perplex me with doubts and fruitless guesses. I often wonder how the sun moves over so large a space every day, and yet seems not to stir out of his place. I would know where he goes beyond the mountains in the evening; what becomes of him in the nighttime; whether he makes his way through the thickness of the earth, or the depth of the sea, and so always shows himself again from the east next morning. It seems strange that, being so small a body as he is, he should still be seen every where, and still of the same bigness. The various nature of the *moon* seems yet more perplexing; to-night, perhaps, you can scarce discern her; but, in a few days, she becomes larger than the body of the sun itself. In a little time after, she decays, and, at last, wears quite away; yet she recovers again. In a word, she is never the same, and yet still becoming what she was before. What means that multitude of stars scattered over the face of the whole sky, whose number is so great that it is become proverbial? There are other things I want to be informed of, but these are the main difficulties which exercise my thoughts, and perplex my mind with endless doubting."

Were the young, or any other class of persons, led to such reflections as these, and were their doubts and inquiries resolved, so far as our knowledge extends, we should have a hundred intelligent observers of the phenomena of the universe for one that is found in the present state of society. But, instead of answering their inquiries and gratifying their natural curiosity, we not unfrequently tell them that they are troublesome with their idle questions; that they ought to mind their grammar and parts of speech, and not meddle with philosophical matters till they be many years older; that such subjects cannot be understood till they become men; and that they must be content to remain in ignorance for ten or twelve years to come. Thus we

frequently display our own ignorance and inattention, and thus we repress the natural desire for knowledge in the young, till they become habituated to ignorance, and till the uneasy sense arising from curiosity and unsatisfied desire has lost its edge, and a desire for sensual or vicious pleasure usurps its place. I recollect, when a boy of about seven or eight years of age, frequently musing on such subjects as those to which we have now alluded. I sometimes looked out from a window, in the daytime, with fixed attention, on a pure azure sky, and sometimes stretched myself on my back on a meadow, or in a garden, and looked up to the zenith to contemplate the blue ethereal. On such occasions a variety of strange ideas sometimes passed through my mind. I wondered how far the blue vault of heaven might extend; whether it was a solid transparent arch, or empty space; what would be seen could I transport myself to the highest point I perceived; and what display the Almighty made of himself in those regions so far removed from mortal view. I asked myself whether the heavens might be bounded on all sides by a solid wall; how far this wall might extend in thickness; or whether there was nothing but empty space, suppose we could fly for ever in any direction. I then entered into a train of inquiries as to what would have been the consequences had neither heaven nor earth been made, and had God alone existed in the boundless void. Why was the world created? What necessity was there why God himself should exist? And why was not all one vast blank, devoid of matter and intelligence? My thoughts ran into wild confusion; they were overwhelming, and they became even oppressive and painful, so as to induce me to put a check to them, and to hasten to my playful associates and amusements. But although my relatives were more intelligent than many of their neighbours, I never thought of broaching such ideas, or of making any inquiries of them respecting the objects which had perplexed my thoughts; and, even if I had, it is not likely I should have received much satisfaction. Such views and reflections are, perhaps, not uncommon in the case of thousands of young people. I mention these things to show that the youthful mind, in consequence of the innate desire of knowledge with which it is endowed, is often in a state peculiarly adapted for receiving instruction on many important subjects, and for becoming an intelligent observer of the economy of nature, were it not that our methods of instruction hitherto, both in public and in private, instead of gratifying juvenile curiosity, have frequently tended to counteract the natural aspirations of the opening mind.

But, leaving such reflections and digressions, let us now take a general view of the motions and phenomena of the nocturnal heavens.

Let us suppose ourselves under the open canopy of heaven in a clear night, at six o'clock in the evening, about the first of November. I fix upon this period, because the *Pleiades*, or seven stars, which are known to every one, are then visible during the whole night, and because, at this season of the year, the most brilliant fixed stars, and the more remarkable constellations, are above the horizon in the evening. Turning our eyes, in the first place, towards the *eastern* quarter of the heavens, we shall see the seven stars just risen above the horizon, in a direction about half way between the east and the north-east points, or east-north-east. North-west from the seven stars, at the distance of thirty degrees, a very bright star, named *Capella*, may be perceived at an elevation of about eighteen degrees above the horizon. Directing our view towards the south, we shall perceive a pretty bright star, with a small star on the north and another on the south of it, which has just passed the meridian. This star is called *Altair*, and belongs to the constellation *Aquila*. It is nearly south, at an elevation of forty-six degrees, or about half way between the horizon and the zenith. About thirty-three degrees north from Altair, and a little farther to the west, is the brilliant star *Lyra*, belonging to the *Harp*. Looking to the west, a bright star, named *Arcturus*, will be seen about fifteen degrees above the horizon, a very little to the north of the western point. Turning our eyes in a northerly direction, the constellation *Ursa Major*, or the Great Bear, presents itself to view. This cluster of stars is sometimes distinguished by the name of the *Plough*, or *Charles's Wain*, and is known to almost every observer. The relative positions of the prominent stars it contains are represented in the following figure. At the time of the evening now supposed, it appears a little to the westward of the northern point of the heavens, the two eastern stars of the square being about eighteen degrees west from that point. These two stars, the uppermost of which is named *Dubhe*, and the lower one *Merak*, are generally distinguished by the name of the *Pointers*, because they *point*, or direct our eye towards the pole-star.

The seven stars in the lower part of the figure are the prominent stars which constitute the tail and the body of the Great Bear. The first of these, reckoning from the left, is termed *Benetnasch*, the second *Mizar*, the third *Alioth*, the fourth *Megrez*, immediately below which is *Phad*. The other two stars,

to the right are the *Pointers* alluded to above. If a line connecting these two stars be considered as prolonged upward to a considerable distance till it meet the first bright star, it directs us to the *pole-star*, which is the one nearest to the pole, and which, to a common observer, never seems to shift its position. The uppermost star in the figure towards the right hand represents the pole-star in its relative distance and position to the Great Bear. The distance between the two pointers, Dubhe and Merak, is about five degrees; and the distance between Dubhe, the uppermost of the pointers, and the pole-star, is about twenty-nine degrees; so that the space between Dubhe and the pole-star is nearly six times the distance between the two pointers. By attending to these circumstances, the distance between any two stars, when expressed in degrees, may be nearly ascertained by the eye. The six small stars in the upper part of the figure represent the constellation *Ursa Minor*, or the Lesser Bear, of which the pole-star forms the tip of the tail. They resemble the configuration of the stars in the Great Bear, only

Fig. 1.

they are on a smaller scale, and in a reversed position.*

Having now fixed on certain stars or points in the heavens as they appear about six in the evening, and marked their relative positions, let us take another view of the celestial vault as it appears about ten o'clock the same evening, or the first clear evening afterward. We shall then find that the seven stars have risen to a considerable elevation, and are nearly half way between the eastern horizon and the south; that the *Bull's-eye*, a bright ruddy star, which was before invisible is now seen a little to the eastward of the Pleiades; and that the brilliant constellation *Orion*, which in the former observation was below the horizon, is now distinctly visible in the east and south-east; and the star *Capella* midway between the horizon and the zenith. The stars *Altair* and *Lyra*, which were before nearly south, have descended more than half way towards the western horizon. The star Arcturus is no longer visible, having sunk beneath the horizon; and many stars in the eastern quarter of the heavens, which were formerly unseen, now make their appearance at different elevations. The stars of the Great Bear, particularly the two pointers, which were formerly to the west of the north point, have now passed to the east of it. At twelve o'clock, midnight, their position may be thus represented.

Fig. 2.
*North.*

*West.* *East.*

The pointers now appear considerably to the eastward of the north point, and considerably more elevated than before, while the stars in the tail appear much lower. About three o'clock next morning the pointers will appear nearly due east from the pole-star, and at the same elevation above the horizon; and the other stars in that constellation will be seen hanging, as it were, nearly perpendicular below them. At this hour the Pleiades, or seven stars, will appear to have moved twenty-five degrees past the meridian to the west, and the brilliant constellation Orion will be seen nearly due south. The bright star Capella now appears nearly in the zenith, or point directly over our heads; Lyra is in the horizon, nearly due north, and Altair has descended below the western horizon. At six in the

* In these observations, the observer is supposed to be placed nearly in 52° north latitude, which is nearly the latitude of London. Those who reside in latitudes between 40° and 45°, as the inhabitants of Philadelphia, New York, Hartford, Boston, Montreal, Madrid, Rome, &c., would require to postpone their observations till a little after half past six in the evening, and to make a small allowance for the elevations, above stated, of certain stars above the horizon. In most other respects, the appearance of the heavens, to the inhabitants of such places, will be the same as here described.

morning, the seven stars will be seen in the west, only a short distance above the horizon; and all the other stars to the eastward of them will be found to have made a considerable progress towards the west. At this hour the stars of the Great Bear will appear near the upper part of the heavens, and the pointers not far from the zenith. Their position at this time is shown in the following figure.

Fig. 3.

Here the pointers appear elevated a great way *above* the pole-star, whereas, in the observation at six in the evening, the whole constellation appeared far *below* it. At eight in the morning, the whole of the constellation would be seen nearly overhead, were the stars then visible; at twelve, noon, it would appear towards the west, at a considerable elevation; and at six in the evening it would again return to its former position, as noted in our first observation. The following figure represents the position of *Ursa Minor*, or the Lesser Bear, at four different periods during twenty-four hours.

Fig. 4.

D

A West. East. C

B

At six in the evening, about the beginning of November, *Ursa Minor* will be nearly in the position represented on the left at *A*, nearly straight west from the pole-star, which appears in the centre. Six hours afterward, or at twelve, midnight, it will appear below the pole, in the position marked *B*; at six next morning it will appear opposite to its first position, as represented on the right at *C*; at twelve, noon, it will appear above the pole, as represented at *D*; but in this position it cannot be seen in November, or during the winter months, as the stars at that time of the day are eclipsed by the light of the sun. At six in the evening it again returns to its former position. Such are the general appearance and apparent motions of all the stars in the northern hemisphere, within fifty-two degrees of the pole, to a spectator situated in 52° of north latitude. They all appear to perform a circuit, in the course of twenty-four hours, around a point which is the centre of their motion, near to which is the pole-star. All the stars within this range never set, but appear to describe complete circles, of different dimensions, around the pole and above the horizon. When they are in the lower part of their course, or beneath the pole, they appear to move from west to east; but when in the higher part of their course, their apparent motion is from east to west; and all their circuits are completed in exactly the same period of time, namely, twenty-three hours, fifty-six minutes, and four seconds.

Let us now consider the appearances which present themselves in the other quarters of the heavens. If we turn our eyes a little to the left of the south, near to that point of the compass called south-south-east, and observe a star near the horizon, such as the star *Fomalhaut*, in the Southern Fish, it will appear to rise to a very small altitude when it comes to the meridian, only about six degrees, and in about five hours it will set near the point south-south-west, having described a very small arc of a circle above the horizon. If we direct our attention to the south-east, and observe any bright star, such as Sirius, or the Dog-star, in the horizon, it will make a larger circuit over the southern sky, and will remain about nine hours above the horizon before it sets in the south-west. If we look due east, and see a star, such as Procyon in the constellation of the Lesser Dog, rising, it will remain about twelve hours above the horizon, and will set in the west. If we look to the north-east, and perceive any stars, such as *Castor* and *Pollux*, beginning to appear, they will make a large circuit round the heavens, such as the sun describes in the month of June, and, after the period of about eighteen hours, will set in the north-west.

Such are the general appearances and the apparent motions of the heavens which pre-

sent themselves when viewed from our northern latitude. Were we to take our station near the Gulf of Guinea, in the island of Sumatra, or Borneo, in the Gallipago Isles, in the city of Quito in South America, or on any other point of the globe near the equator, the motions of the stars would appear somewhat different. The pole-star, instead of being at a high elevation, as in our latitude, would be in the horizon. All the stars would appear to rise and set, and the time of their continuance above the horizon would be precisely the same. The stars which rise in the east would ascend to the zenith, and pass directly overhead, in the course of six hours; and in another six hours they would descend to the horizon, and set in the western point. The stars near the northern and southern points would appear to describe small semicircles above the horizon during the same time, and their motion would appear much slower. The Great Bear, which never sets in our latitude, would be above the horizon only during the one half of its circuit. Many stars and constellations would appear in the southern quarter of the sky which we never see in our latitude. Every star would be found to remain exactly twelve hours above and twelve hours below the horizon, and all the visible stars in the firmament might, from such a position, be perceived in the course of a year. Were we to take our station in the southern hemisphere, in Valdivia, Botany Bay, or Van Diemen's Land, the heavens would present a different aspect from any of those we have yet contemplated. The north pole-star, the Great Bear, and other neighbouring constellations, would never appear above the horizon. Many of the stars which we now see in the south would appear in the north. The south pole would appear elevated about forty degrees above the horizon, and various clusters of stars would be seen revolving round it, as the Great Bear and other constellations do around the north pole. In fine, could we take our station at ninety degrees of north latitude, or, in other words, at the north pole of the world, we should just see one half of the stars of heaven, and no portion of the other half would ever be visible. These stars would appear neither to rise nor set, nor yet to stand still. They would appear to move round the whole heavens, in circles parallel to the horizon, every twenty four hours; and on very clear evening all the stars that are ever visible in that hemisphere may be seen. The stars, however, that appear in a certain direction at any particular hour will appear at the same elevation in the opposite direction twelve hours afterward; and during nearly six months no stars will be seen in the sky.

The apparent motion of the heavens may at any time be perceived by fixing on any star that appears nearly in a line with a tree, a spire, or any other fixed object, and in the course of a few minutes its motion will be perceptible; or, fix a common telescope upon a pedestal, and direct it to any star, and in three or four minutes it will be seen to have passed out of the field of view. In the description now given, I have spoken of the *pole-star* as if it were actually the pole, or the most northerly point of the heavens. But it may be proper to state, that though it is the nearest large star to that point, it is not actually in the pole; it is somewhat more than a degree and a half from the polar point, and revolves around that point, in a small circle, every twenty-four hours. This motion may be perceived by directing a telescope of a moderate magnifying power to this star, and fixing it in that position, when, in the course of an hour or two, it will be found to have moved beyond the field of view.

All the observations above stated (excepting those supposed to have been made at the equator, and in southern latitudes) may be accomplished in the course of two or three evenings, without incurring the loss of a couple of hours; for each observation may be made in the space of five or ten minutes. Every inhabitant of the globe has an opportunity, if he choose, of observing the aspect of the heavens in the manner now described, excepting, perhaps, those who live in dark and narrow lanes, in large cities, where the sky is scarcely visible; the most unnatural situations in which human beings can be placed, and which ought no longer to remain as the abodes of men. And the man who will not give himself the trouble of making such observations on the starry heavens deserves to remain in ignorance of the most sublime operations of the Creator.

Let us now consider what is the conclusion we ought to deduce from our observations respecting the apparent motion of the heavens. All the phenomena which we have described, when duly considered and compared together, conspire to show that *the whole celestial vault performs an apparent revolution round the earth*, carrying, as it were, all the stars along with it, in the space of twenty-four hours. This may be plainly demonstrated by means of a celestial globe, on which all the visible stars are depicted. When the north pole is elevated fifty-two degrees above the northern horizon, and the globe turned round on its axis, all the variety of phenomena formerly described may be clearly perceived.

Here, then, we have presented to view a scene the most magnificent and sublime. All the bright luminaries of the firmanent revolving in silent grandeur around our world; not only the stars visible to the unassisted eye, but all

the ten thousands and millions of stars which the telescope has enabled us to descry in every region of the heavens, for they all seem to partake of the same general motion. If we could suppose this motion to be *real*, it would convey to the mind the most magnificent and impressive idea which could possibly be formed of the incomprehensible energies of Omnipotence. For here we have presented to view, not only ten thousand times ten thousands of immense globes, far superior to the whole earth in magnitude, but the greater part of them carried round in their revolutions with a velocity that baffles the power of the most capacious mind to conceive. In this case, there would be millions of those vast luminaries, which behooved to move at the rate of several thousands of millions of miles *in the space of a second of time.* For in proportion to the distances of any of these bodies would be the rapidity of their motions. The nearest star would move more than fourteen hundred millions of miles during the time in which the pendulum of a clock moves from one side to another; but there are thousands of stars visible through our telescopes at least a hundred times more distant, and whose distance cannot be less than 2,000,000,000,000,000, or two thousand billions of miles. This forms the radius, or half diameter of a circle whose circumference is about 12,500,000,000,000,000, or twelve thousand five hundred billions of miles. Around this circumference, therefore, the star behooved to move every day. In a sidereal day of twenty-three hours, fifty-six minutes, and four seconds, there are 86,164 seconds. Divide the number of miles in the circumference by the number of seconds in a day, and the quotient will be somewhat more than 145,000,000,000, or one hundred and forty-five thousand millions, which is the number of miles that such a star would move in the space of a second, or during the pulsation of an artery, were the celestial vault to be considered as really in motion; a rate of motion more than a hundred thousand millions of times greater than that of a cannon ball, and seven hundred thousand times more rapid than the motion of light itself, which is considered the swiftest motion in nature.

The idea of such astonishing velocities completely overpowers the human imagination, and is absolutely inconceivable. We perceive no objects or motions connected with our globe that can assist our imagination in forming any definite conceptions on this subject. The swiftest impulse that was ever given to a cannon ball, or any other projectile, sinks into nothing in the comparison, Were we transported to the planet Saturn, and placed on its equatorial regions, we should behold a stupendous arch, thirty thousand miles in breadth, and more than six hundred thousand miles in circumference, revolving around us every ten hours, at the rate of a thousand miles in a minute, and sixty thousand miles every hour. But even this astonishingly rapid motion would afford us little assistance in forming our conceptions, as it bears no comparison with the motions to which we have now adverted. It becomes those persons, therefore, who refuse to admit the motion of the earth, to consider, and to ponder with attention, the only other alternative which *must be* admitted, namely, that all the bodies of the firmament move round the earth every day with such amazing velocities as have now been stated. If it appear wonderful that this globe of the land and water, with all its mighty cities and vast population, moves round its axis every day at the rate of a thousand miles an hour, how much more wonderful, and passing all comprehension, that myriads of huge globes should move round the earth in the same time with such inconceivable rapidity. If we reject the motion of the earth because it is incomprehensible and contrary to all our preconceived notions, we must, on the same ground, likewise reject the motion of the heavens, which is far more difficult to be conceived, and consequently fall into downright skepticism, and reject even the evidence of our senses as to what appears in the economy of nature. Such views and considerations, however, teach us that, in whatever point of view we contemplate the works of the Almighty, particularly the scenery of the heavens, the mind is irresistibly inspired with sentiments of admiration and wonder. To the vulgar eye as well as to the philosophic, "the heavens declare the glory of God." Their harmony and order evince his wisdom and intelligence; and the numerous bodies they contain, and the astonishing motions they exhibit, on whatever hypothesis they are contemplated, demonstrate both to the savage and the sage the existence of a power which no created being can control.

> "View the amazing canopy!
> The wide, the wonderful expanse!
> Let each bold infidel agree
> That God is there, unknown to chance."

We cannot, however, admit, in consistency with the dictates of enlightened reason, that the apparent diurnal movements of the stars are the *real* motions with which these bodies are impelled. For, in the first place, *such motions are altogether unnecessary* to produce the effect intended, namely, the alternate succession of day and night with respect to our globe; and we know that the Almighty does nothing in vain, but employs the most simple means to accomplish the most astonishing and important ends. The succession of day and

night can be accomplished by a simple rotation of the earth from west to east every twenty-four hours, which will completely account for the apparent motion of the heavens, in the same time, from east to west. This we find to be the case with Jupiter and Saturn, which are a thousand times larger than the earth, as well as with the other planets, which have a rotation round their axes, some in ten hours, some in twenty-three, and some in ten hours and a half; and, consequently, from the surfaces of these bodies the heavens *will appear* to revolve around them in another direction from what they do to us, and, in certain instances, with a much greater degree of velocity. We must therefore conclude that our motion every day towards the east causes the heavens to appear as if they moved towards the west; just as the trees and houses on the side of a narrow river appear to move to the west when we are sailing down its current in a steamboat towards the east.

2. *Because it is impossible to conceive that so many bodies of different magnitudes, and at different distances from the earth, could all have the same period of diurnal revolution.* The sun is four hundred times further from us than the moon, and is sixty millions of times larger. Saturn and Herschel are still further from the earth; the comets are of different sizes, and traverse the heavens in all directions and at different distances; the fixed stars are evidently placed at different distances from the earth and from each other; yet all these bodies have exactly the same period of revolution, even to a single moment, if the heavens revolve around the earth, and that, too, notwithstanding the other motions, in various directions, which many of them perform. It is, therefore, much more natural and reasonable to suppose that the earth revolves around its axis, since this circumstance solves all the phenomena and removes every difficulty.

3. Because *such a rate of motion in the heavenly bodies*, if it could be supposed to exist, *would soon shatter them to atoms.* Were a ball of wood to be projected from a canon at the rate of a thousand miles an hour, in a few moments it would be reduced to splinters; and hence the forage and other soft substances projected from a musket or a piece of ordnance are instantly torn to pieces. What, then, might be supposed to be the consequence, were a body impelled through the regions of space with a velocity of a hundred and forty thousand millions of miles in a moment of time? It would most assuredly reduce to atoms the most compact bodies in the universe, although they were composed of substances harder than adamant. But as the fixed stars appear to be bodies of a nature somewhat similar to the sun, and as the sun is much less dense than the earth, and only a little denser than water, it is evident that they could not withstand such a rapidity of motion, which would instantly shatter their constitution, and dissipate every portion of their substance through the voids of space.

4. Because *there is no known instance in the universe* (if that to which we are now adverting be excepted) *of a larger body revolving around a smaller.* The planet Jupiter does not revolve around his satellites, which are a thousand times less than that ponderous globe, but they all revolve around him; nor does the earth, which is fifty times larger than the moon, revolve around that nocturnal luminary, but she regularly revolves about the earth, as the more immediate centre of her motion. The sun does not perform his revolution around Venus or Mercury, but these planets, which are small, compared with that mighty orb, continually revolve about him as the centre of their motions. Neither on earth nor in the heavens is there an instance to be found contrary to this law, which appears to pervade the whole system of universal nature; but if the diurnal revolution of the stars is to be considered as their proper motion, then the whole universe, with all the myriads of huge globes it contains, is to be considered as daily revolving around an inconsiderable ball, which, when compared with these luminaries, is only as an atom to the sun, or as the smallest particle of vapour to the vast ocean.

5. The apparent motion of the heavens cannot be admitted as *real, because it would confound all our ideas of the intelligence of the Deity.* While it tended to exalt our conceptions of his omnipotence to the highest pitch, it would convey to us a most unworthy and distorted idea of his *wisdom.* Wisdom is that perfection of an intelligent agent which enables him to proportionate one thing to another, and to devise the most proper *means* in order to accomplish important *ends.* We infer that an artist is a wise man from the nature of his workmanship, and the methods he employs to accomplish his purposes. We should reckon that person foolish in the extreme who should construct, at a great expense, a huge and clumsy piece of machinery for carrying round a grate, and the wall of a house to which it is attached, for the purpose of roasting a small fowl placed in the centre of its motion, instead of making the fowl turn round its different sides to the fire. We should consider it as the most preposterous project that was ever devised were a community to attempt, by machinery, to make a town and its harbour move forward to meet every boat and small vessel that entered the river on which it was situated, instead of allowing such vehicles to move onward as they

do at present. But none of these schemes would be half so preposterous as to suppose that the vast universe moves daily round an inconsiderable ball, when no end is accomplished by such a revolution but what may be effected in the most simple manner. Such a device, therefore, cannot be any part of the arrangements of Infinite Wisdom. It would tend to lessen our ideas of the *intelligence* of that adorable Being who is "wonderful in counsel and excellent in working," who "established the world by his wisdom, and stretched out the heavens by his understanding," and whose wisdom as far excels that of man as the "heaven in its height surpasses the earth." This argument alone I consider as demonstrative of the position we are now attempting to support.

The above are a few arguments which, when properly weighed, ought to carry conviction to the mind of every rational inquirer, that the general motion which appears in the starry heavens is not real, but is caused by the rotation of the earth round its axis every day, by which we and all the inhabitants of the globe are carried round in a regular and uniform motion from west to east. When this conclusion is admitted, it removes every difficulty and every disproportion which at first appeared in the motions and arrangements of the celestial orbs, and reduces the system of the universe to a scene of beauty, harmony, and order worthy of the infinite wisdom of Him who formed the plan of the mighty fabric, and who settled "the ordinances of heaven." Instead, then, of remaining in a state of absolute rest, as we are at first apt to imagine, we are transported every moment towards the east with a motion ten times more rapid than has ever been effected by steam-carriages or air-balloons. It is true, we do not feel this motion, because it is smooth and uniform, and is never interrupted. The earth is carried forward in its course, not like a ship in the midst of a tempestuous ocean, but through a smooth ethereal sea, where all is calm and serene, and where no commotions to disturb its motion ever arise. Carried along with a velocity which is common to every thing around us, we are in a state somewhat similar to that of a person in a ship which is sailing with rapidity in a smooth current; he feels no motion except when a large wave or other body happens to dash against the vessel; he fancies himself at rest, while the shore, the buildings, and the hills appear to him to move; but the smallness of the vessel, compared with the largeness of the objects which seem to move, convinces him that the motion is connected with the ship in which he sails: and on similar principles we infer that the apparent motion of the heavens is caused by the real motion of the earth, which carries us along with it as a ship carries its passengers along the sea. With regard to motion, it may be observed that, strictly speaking, we do not *perceive* any motion either in the earth or in the heavens. When we look at a star with the utmost steadiness, we perceive no motion, although we keep our eye fixed upon it for a few minutes; but, if we mark the position of the star with regard to a tree or a chimney top, and, after an hour or two, view the star from the same station, we shall find that it then appears in a different direction. Hence we infer that motion has taken place; but whether the motion be in the star or in the persons who have been observing it, remains still to be determined. We perceive no motion in the star any more than we feel the motion of the earth. All that we perceive is, that the two objects have changed their relative positions; and, therefore, the body that is really in motion must be determined by such considerations as we have stated above.

Besides the apparent diurnal revolution of the heavens, there is another apparent motion which requires to be considered. It is well known to every one who has paid the least attention to this subject, that we do not perceive the same clusters of stars at every season of the year. If, for example, we take a view of the starry heavens on the first of October, at ten o'clock in the evening, and again, at the same hour, on the first of April, we shall find that the clusters of stars in the southern parts of the heavens are, at the latter period, altogether different from those which appeared in the former; and those which are in the neighbourhood of the pole will appear in a different position in April from what they did at the same hour in the month of October. The square of the *Great Bear*, for example, will appear immediately *below* the pole-star in October; whereas in April it will appear as far *above* it, and near to the zenith. In the former case, the two stars called the *Pointers* will point *upward* to the pole, in the latter case they will point *downward*. In October this constellation will appear nearly in the position represented in fig. 1 (p. 14); in April it will appear nearly as represented in fig. 3 (p. 15). These variations in the appearance of the stars lead us to conclude that there is an *apparent annual motion* in these luminaries. This motion may be observed, if we take notice, for a few days or weeks, of those stars which are situated near the path of the sun. When we see a bright star near the western horizon, a little elevated above the place where the sun went down, if we continue our observation we shall find that every day it appears less elevated at the same hour, and seems to be gradually approaching

to the point of the heavens in which the sun is situated, till, in the course of a week or two, it ceases to be visible, being overpowered by the superior brightness of the sun. In the course of a month or two the same star which disappeared in the west will be seen rising some time before the sun in the east, having passed from the eastern side of the sun to a distance considerably westward of him. The stars in the western quarter of the heavens which appeared more elevated will be found gradually to approximate to the sun, till they likewise disappear; and in this manner all the stars of heaven seem to have a revolution, distinct from their diurnal, from east to west, which is accomplished in the course of a year.

The different positions of the *Pleiades*, or seven stars, at different seasons of the year, will afford every observer an opportunity of perceiving this motion. About the middle of September these stars will be seen, about eight o'clock in the evening, a little to the south of the north-east point of the horizon; about the middle of January, *at the same hour*, they will be seen on the meridian, or due south; on the first of March they will be seen half way between the zenith and the western horizon; about the middle of April they will appear very near the horizon; soon after which they will be overpowered by the solar rays, and will remain invisible for nearly two months, after which they will reappear in the east, early in the morning, before the rising sun.

This annual motion of the stars evidently indicates that the sun has an *apparent* motion every day from *west* to *east*, contrary to his apparent diurnal motion, which is from east to west. This apparent motion is at the rate of nearly *a degree* every day, a space nearly equal to twice the sun's apparent diameter. In this way the sun appears to describe a circle around the whole heavens, from west to east, in the course of a year. This apparent motion of the sun is caused by the *annual* revolution of the earth around the sun as the centre of its motion, which completely accounts for all the apparent movements in the sun and stars to which we have now adverted. If we place a candle upon a table in the midst of a room, and walk round it in a circle, and, as we proceed, mark the different parts of the opposite walls with which the candle appears coincident, when we have completed our circle the candle will appear to have made a revolution round the room. If the walls be conceived to represent the starry heavens, and the candle the sun, it will convey a rude idea of the apparent motion of the sun, and the different clusters of stars which appear at different seasons of the year in consequence of the annual motion of the earth. But this subject will be more particularly explained in the sequel.

From what we have now stated in relation to the apparent motions of the heavens, we are necessarily led to conceive of the earth as a body, placed, as it were, in the midst of infinite space, and surrounded in every direction, above, below, on the right hand and on the left, with the luminaries of heaven, which display their radiance from every quarter at immeasurable distances; and that its annual and diurnal motions account for all the movements which appear in the celestial sphere. Hence it is a necessary conclusion, that we are surrounded at all times with a host of stars, in the *daytime* as well as in the night, although they are then imperceptible. The reason why they are invisible during the day is obviously that their fainter light is overpowered by the more vivid splendour of the sun and the reflective power of the atmosphere. But although they are then imperceptible to the unassisted eye, they can be distinctly perceived, not only in the mornings and evenings, but even at noonday, while the sun is shining bright, by means of telescopes adapted to an equatorial motion; and in this way almost every star visible to the naked eye at night can be pointed out, even amid the effulgence of day, when it is within the boundary of our hemisphere. When the stars which appear in our sky at night have, in consequence of the rotation of the earth, passed from our view, in about twelve hours afterward they will make their appearance nearly in the same manner to those who live on the opposite side of the globe; and when they have cheered the inhabitants of those places with their radiance, they will again return to adorn our nocturnal sky.

On the whole, *the starry heavens present, even to the vulgar eye, a scene of grandeur and magnificence.* We know not the particular destination of each of those luminous globes which emit their radiance to us from afar, or the specific ends it is intended to subserve in the station which it occupies, though we cannot doubt that all of them answer purposes in the Creator's plan worthy of his perfections and of their magnitude and grandeur; but we are certain that they have, at least, a remote relation to man, as well as to other beings far removed from us, in the decorations they throw around his earthly mansion. They serve as a glorious ceiling to his habitation. Like so many thousand sparkling lustres, they are hung up in the magnificent canopy which covers his abode. He perceives them shining and glittering on every hand, and the dark azure which surrounds them contributes to augment their splendour. The variety of

lustre which appears in every star, from those of the sixth magnitude to those of the first, and the multifarious figures of the different constellations, present a scene as diversified as it is brilliant. What are all the decorations of a Vauxhall Garden, with its thousands of variegated lamps, compared with ten thousands of suns, diffusing their beams over our habitation from regions of space immeasurably distant? A mere gewgaw in comparison; and yet there are thousands who eagerly flock to such gaudy shows who have never spent an hour in contemplating the glories of the firmament, which may be beheld "without money and without price." That man who has never looked up with serious attention to the motions and arrangements of the heavenly orbs must be inspired with but a slender degree of reverence for the Almighty Creator, and devoid of taste for enjoying the beautiful and the sublime.

The stars not only adorn the roof of our sublunary mansion, but they are also in many respects *useful* to man. Their influences are placid and gentle. Their rays, being dispersed through spaces so vast and immense, are entirely destitute of heat by the time they arrive at our abode; so that we enjoy the view of a more numerous assemblage of luminous globes without any danger of their destroying the coolness of the night or the quiet of our repose. They serve to guide the traveller both by sea and land; they direct the navigator in tracing his course from one continent to another through the pathless ocean. They serve "for signs and for seasons, and for days and years." They direct the labours of the husbandman, and determine the return and conclusion of the season. They serve as a magnificent "timepiece" to determine the true length of the day and of the year, and to mark with accuracy all their subordinate divisions. They assist us in our commerce, and in endeavouring to propagate religion among the nations, by showing us our path to every region of the earth. They have enabled us to measure the circumference of the globe, to ascertain the *density* of the materials of which it is composed, and to determine the exact position of all places upon its surface. They cheer the long nights of several months in the polar regions, which would otherwise be overspread with impenetrable darkness. Above all, they open a prospect into the regions of other worlds, and tend to amplify our views of that Almighty Being who brought them into existence by his power, and "whose kingdom ruleth over all." In these arrangements of the stars in reference to our globe, the Divine wisdom and goodness may be clearly perceived. We enjoy all the advantages to which we have alluded as much as if the stars had been created solely for the use of our world, while, at the same time, they serve to diversify the nocturnal sky of other planets, and to diffuse their light and influence over ten thousands of other worlds with which they are more immediately connected; so that, in this respect, as well as in every other, the Almighty produces the most sublime and diversified effects by means the most simple and economical, and renders every part of the universe subservient to another, and to the good of the whole.

Before proceeding further, it may be expedient to explain the *measures* by which astronomers estimate the apparent distances between any two points of the heavens. Every circle is supposed to be divided into 360 equal parts. A circle which surrounds the concavity of the heavens, as that which surrounds an artificial globe, is divided into the same number of parts. The number 360 is entirely arbitrary, and any other number, had mathematicians chosen, might have been fixed upon: and hence the French, in their measures of the circle, divide it into 400 equal parts or degrees; each degree into 100 minutes, and each minute into 100 seconds. The reason why the number 360 appears to have been selected is, that this number may be divided into halves, quarters, and eighths, without a fraction; and, perhaps, because the year was, in former times, supposed to contain about 360 days. Each degree is divided into sixty minutes, each minute into sixty seconds, each second into sixty thirds, &c. Degrees are marked thus, °; minute, ′; seconds, ″; thirds, ‴. Thus the obliquity of the ecliptic for January 1st, 1836, was twenty-three degrees, twenty-seven minutes, forty-two seconds, which are thus expressed, 23° 27′ 42″.

It may not be improper to remark, that when we state the number of degrees between two objects, either on the earth or in the heavens, it is not intented to express the *real* distance, but only the *relative* or *apparent* distance of the objects. Thus, when we say that two places on the earth, which lie directly north and south of each other, are twenty degrees distant, it does not convey an idea of the *actual distance* of these places from each other, but only what proportion of the earth's circumference intervenes between them. If, however, we know the number of yards or miles contained in that circumference, or in a single degree of it, we can then find the actual distance, by multiplying the number of degrees by the number of miles in a degree. But this supposes that the extent of a degree on the earth's surface has been measured, and the number of yards or miles it contains ascertained. In like manner, when we say that two stars in the heavens are fifteen degrees

from each other, this merely expresses their relative position, or what portion of a great circle of the celestial sphere intervenes between them, but determines nothing as to their real distance, which is far surpassing our comprehension. The real magnitude of objects or spaces in the heavens depends upon their distance. Thus, the apparent breadth or diameter of the moon is about half a degree, or nearly thirty two minutes, and that of the sun nearly the same; but as the moon is much nearer to us than the sun, *a minute of a degree* on her surface is equal only to about seventy miles, while a minute on the sun's surface is equal to more than 28,000 miles, which is four hundred times greater. The greatest apparent diameter of Saturn is twenty seconds, or one third of a minute the greatest diameter of Venus is fifty-eight seconds, or nearly a minute; but as Saturn is much further from us than Venus, his real diameter is 79,000 miles, while that of Venus is only 7,700. Before the real diameter of any object in the heavens can be determined, its distance must be first ascertained.

Those who have never been in the practice of applying angular instruments to the heavens may aquire a tolerably correct idea of the extent of space which is expressed by any number of degrees by considering that the apparent diameters of the sun and moon are about *half a degree;* that the distance between the two pointers in the Great Bear is about five degrees; that the distance between the pole-star and the nearest pointer is twenty-nine degrees; that the distance between the *Pleiades* and the raddy star *Aldebaran*, which lies to the eastward of these stars, is fourteen degrees; that the distance between *Castor* and *Pollux* is five degrees; and the distance between *Bellatrix* and *Betelguese*, the stars in the right and left shoulder of *Orion*, is eight degrees. Perhaps the most definite measure for a common observer is that which is to be found in the three stars in a straight line which form the *belt* of Orion, which are known to every one, and which are distinguished in England by the name of the *Three Kings*, or the *Ell* and *Yard*, and in Scotland by "*The Lady's Elwand.*" The line which unites these three stars measures exactly three degrees, and, consequently, there is just one and a half degree between the central star and the one on each side of it. By applying this rule or yard to any of the spaces of the firmament, the number of degrees which intervenes between any two objects may be nearly ascertained. Orion is the most striking and splendid of all the constellations; and as the equator runs through the middle of it, it is visible from all the habitable parts of the globe. About the middle of January it is nearly due south at nine o'clock in the evening.

I have been somewhat particular in the above sketches of the apparent motions and phenomena of the heavens, because such descriptions are seldom or never given in elementary treatises; because I wish every lover of the science of astronomy to contemplate with his own eyes the scenery of the sky; and because such views and observations of the general aspect of the heavens are necessary in order to understand the true system of the universe.

## CHAPTER II.

### *On the general arrangement of the Planetary System.*

When we take an attentive view of the nocturnal heavens at different periods, we find that the stars never shift their positions with respect to each other. The stars, for instance, that form the constellation of Orion, preserve the same relative positions to each other every succeeding day, and month, and year. They exhibit the same general figure which they presented in the days of our fathers, and even in the times of Amos and of Job. We never see the three stars in the belt, which Job calls "the bands of Orion," move nearer to, or farther from, each other. We never see the pointers in the Great Bear directed on any other line than towards the pole-star, nor do we see *Aldebaran* to the north or south, or to the west, of the seven stars; and the same may be said, with two or three exceptions, in regard to all the stars in the heavens, which preserve invariably the same general relations to each other from one year and century to another. Hence they have been denominated *fixed stars.* But when an attentive observer surveys the heavens with minuteness, he will occasionally perceive some bodies that shift their positions. When the movements of these bodies are carefully marked, they will be found to direct their course sometimes to the east, at other times to the west, and at certain times to remain in a fixed position; but on the whole, their motion is generally from west to east. Their

motion is perceived by their appearing sometimes on one side of a star and sometimes on another. They appear to partake of the general diurnal motion of the heavens, and rise and set with the stars to which they are adjacent. These bodies have received the name of *planets*, that is *wandering stars;* and, indeed, were their real motions such as they appear to a common observer, the name would be exceedingly appropriate. For their apparent motions are in many instances exceedingly irregular; and, were they delineated on paper, or attempted to be exhibited by machinery, they would appear an almost inextricable maze. Ten bodies of this description have been discovered in the heavens, five of which are invisible to the naked eye, and can only be perceived by means of telescopes. They were, of course, unknown to the ancients. The names of the five which have been known in all ages are, Mercury, Venus, Mars, Jupiter, and Saturn. The names of the other five, which have been discovered within the last sixty years, are, Vesta, Juno, Ceres, Pallas, and Uranus, or Herschel.

It was long before the true magnitudes and real motions of these globes were fully ascertained. Most of the ancient astronomers supposed that the earth was a quiescent body in the centre of the universe, and that the planets revolved around it in so many different heavens, which were nearly concentric, and raised one above another in a certain order. The first or lowest sphere was the *Moon*, then *Mercury*, and, next in order, *Venus*, the *Sun*, *Mars*, *Jupiter*, *Saturn*, and then the sphere of the fixed stars. They found it no easy matter to reconcile the daily motion, which carries the stars from east to west, with another peculiar and slow motion, which carries them round the poles of the ecliptic, and from west to east, in the period of 25,000 years; and, at the same time, with a third motion, which carries them along from east to west in a year, around the poles of the ecliptic. They were no less at a loss how to reconcile the *annual* and *daily* motions of the sun, which are directly contrary to each other. An additional difficulty was found in the particular course pursued by each individual planet. It required no little ingenuity to invent celestial machinery to account for all the variety of motions which appeared among the heavenly orbs. After the first *mobiles*, or powers of motion, they placed some very large heavens of solid crystal, which, by rolling one over another, and by a mutual and violent clashing, communicated to each other the universal motion received from the *primum mobile*, or first mover; while, by a contrary motion, they resisted this general impression, and, by degrees, carried away, each after its own manner, the planet for the service of which it was designed. These heavens were conceived to be *solid;* otherwise the upper ones could have had no influence on the lower to make them perform their daily motion, and they behooved to be of the *finest crystal*, because the light of the stars could not otherwise penetrate the thickness of these arches applied one over another, nor reach our eyes. Above the sphere of the fixed stars were placed the first and second crystalline heavens, and above these the *primum mobile*, which carried round all the subordinate spheres. They imagined that the *primum mobile* was circumscribed by the empyreal heaven, of a cubic form, which they supposed to be the blessed abode of departed souls. Some astronomers were contented with seven or eight different spheres, while others imagined no less than seventy of them wrapped up one within another, and all in separate motions. They no sooner discovered some new motion or effect, formerly unknown, that they immediately set to work and patched up a new sphere, giving it such motions and directions as were deemed requisite. Cycles, epicycles, deferents, centric and eccentric circles, solid spheres, and other celestial machinery, were all employed to solve the intricate motions of the heavens, which seemed to baffle all the efforts of human ingenuity. After their system was supposed to be completed, new anomalies were detected, which required new pieces of machinery to be applied to solve appearances. But after all the ingenuity displayed in their patchings and repatchings, the celestial spheres could never be got to move onward in harmony, and in accordance with the phenomena of the heavens.*

It would be no easy task to describe how their epicycles could be made to move through the thick crusts of crystal of which their spheres were made. They, however, found some means or other to extricate themselves from every difficulty, as they always had recourse to geometrical lines, which never found any obstacle to their passage on paper. To make all the pieces of their machinery move with as much smoothness and as little inconsistency as possible, they were forced to delineate certain furrows, or to notch on the arches certain grooves, in which they jointed and made the tenons and mortises of their epicycles to slide. All this celestial joiner's work, to which succeeding astronomers added several pieces to produce balancings, or perpetual goings backward and forward, had no other tendency than to conceal the sublime and beautiful simplicity of nature, and to prevent mankind, for many ages, from recognizing the true system of the world. With all their

* See La Pluche's "*Spectacle de la Nature.*"

cumbrous and complicated machinery, they never could account for the motions and other phenomena of Mercury and Venus, and the different apparent magnitudes which the planets present in different parts of their orbits. Without admitting the motion of the earth, it would surpass the wisdom of an angel, on any rational principles, to solve the phenomena of the heavens. This is the system which has been denominated the *Ptolemaic*, from Ptolemy, an astronomer in Egypt, who first gave a particular explanation of its details; but it is understood to have been received by the ancient Greek philosophers, except the Pythagoreans. It was supported by Aristotle, who wrote against the motion of the earth; and as the authority of this philosopher was thought sufficient to establish the opinion of the earth being a quiescent body, it was generally received by the learned in Europe till the sixteenth century, or a little after the period of the Reformation. This is the system to which almost all our theological writers, even of the seventeenth century, uniformly refer, when alluding to the heavenly bodies and to the general frame of the world; and, in consequence of admitting so absurd and untenable a theory, their reflections and remarks in reference to the objects of the visible world, and many of their comments on scripture, are frequently injudicious and puerile, and, in many instances, worse than useless. That such a clumsy and bungling system was so long in vogue, is a disgrace to the ages in which it prevailed, and shows that even the learned were more prone to frame hypotheses and to submit to the authority of Aristotle, than to follow the path of observation, and to contemplate with their own eyes the phenomena of the universe. To suppose that the Architect of nature was the author of such a complex and clumsy piece of machinery was little short of a libel on his perfections, and a virtual denial of his infinite wisdom and intelligence.

"Oh how unlike the complex works of man,
Heaven's easy, artless, unencumber'd plan!"

From this brief sketch of the Ptolemaic system, we may learn into how many absurdities we involve ourselves by the denial of a single important fact and the admission of a single false principle; and the importance of substantiating every fact and proving every principle in all our investigations of the system of nature and the order of the universe.

The first among the moderns who had the boldness to assail the ancient system which had so long prevailed was the famous *Nicolaus Copernicus*, who was born at Thorn, in Polish Prussia, in 1472, and died at Worms, where he had been made a canon of the church by his mother's brother, who was bishop of that place. His attention was early directed to the sciences of mathematics and astronomy. Having travelled into Italy for the purpose of enlarging his knowledge on such subjects, he remained some time at Belogna with Dominicus Maria, an eminent professor of astronomy, and afterward went to Rome, where he soon acquired so great a reputation that he was chosen professor of mathematics, which he taught for a long time with great applause. At the same time he was unwearied in making celestial observations. Returning to his own country, he began to apply his vast knowledge in mathematics to correct the system of astronomy which then prevailed. Having applied himself with assiduity to the study of the heavens, he soon perceived that the hypothesis of the ancient astronomers was conformable neither to harmony, uniformity, nor reason. With a bold independent spirit, and a daring hand, he dashed the crystalline spheres of Ptolemy to pieces, swept away his cycles, epicycles, and deferents, stopped the rapid whirl of the primum mobile, fixed the sun in the centre of the planetary orbs, removed the earth from its quiescent state, and set it in motion through the ethereal void along with the other planets, and thus introduced simplicity and harmony into the system of the universe. But such a bold attack on ancient systems, which had been so long venerated, could not be made without danger. Even the learned set themselves in opposition to such bold innovations in philosophy; the vulgar considered such doctrines as chimeras, contrary to the evidence of their senses, and allied to the ravings of a maniac; and the church thundered its anathemas against all such opinions as most dangerous heresies. When only about thirty-five years of age, Copernicus wrote his book "On the Revolution of the Celestial Orbs;" but, fearing the obloquy and persecution to which his opinions might expose him, he withheld its publication, and communicated his views only to a few friends. For more than thirty years he postponed the publishing of this celebrated work, in which his system is demonstrated; and it was with the utmost difficulty, even in the latter part of his life, that he could be prevailed upon to usher it into the world. Overcome, at length, by the importunity of his friends, he put the work in order, and dedicated it to Pope Paul III.; in which dedication, not to shock received prejudices, he presented his system under the form of a hypothesis. "Astronomers," said he, "being permitted to imagine circles to explain the motion of the stars, I thought myself equally entitled to examine if the supposition of the motion of the earth would

render the theory of these appearances more exact and simple." The work was printed at Nuremberg at the expense of his friends, who wrote a preface to it, in order to palliate, as much as possible, so extraordinary an innovation. But its immortal author did not live to behold the success of his work. He was attacked by a bloody flux, which was succeeded by a palsy in his left side; and only a few hours before he breathed his last he received a copy of his work, which had been sent him by one of his scientific friends. But he had then other cases upon his mind, and composedly resigned his soul to God on the 23d of May, 1543, in the seventy-first year of his age. His remains were deposited in the cathedral of Frauenberg; and spheres cut in relief on his tomb were the only epitaph that recorded his labours. Not many years ago his bones were wantonly carried off to gratify the impious curiosity of two Polish travellers.*

The system broached by Copernicus, notwithstanding much opposition, soon made its way among the learned in Europe. It was afterwards powerfully supported by the observations and reasonings of Galileo, Kepler, Halley, Newton, La Place, and other celebrated philosophers, and now rests on a foundation firm and immutable as the laws of the universe. The introduction of this system may be considered an era as important in philosophy as that of the Reformation was in politics and religion. It had even a bearing upon the progress of religion itself, and upon the views we ought to take of the character and operations of the great Creator. It paved the way for a rational contemplation of his works, and for all those brilliant discoveries in the celestial regions which have expanded our views of his adorable perfections, and of the boundless extent of his universal empire. It was promulgated nearly at the same period when the superstitions of the dark ages were beginning to be dissipated; when the power of the Romish church had lost its ascendency; when the art of printing had begun to illuminate the world; when the mariner's compass was applied to the art of navigation; when the western continent was discovered by Columbus; and when knowledge was beginning to diffuse its benign influence over the nations; and, therefore, it may be considered as connected with that series of events which are destined, in the moral government of God, to enlighten and renovate the world.

I shall now proceed to consider the arrangement of the planetary or Copernican system, and some of the arguments by which it is supported.

In this system the sun is considered as placed near the centre. Around this central luminary the planets perform their revolutions in the following order:—First, the planet Mercury, at the distance from the sun's centre of about 37 millions of miles. Next to Mercury is Venus, distinguished by the name of the morning and evening star, at the distance of 31 millions of miles from the orbit of Mercury, and 68 millions from the sun. The Earth is considered as the planet next in order, which revolves at the distance of 95 millions of miles from the sun, and 27 millions from the orbit of Venus. Farther from the sun than the Earth is the planet Mars, which is 145 millions of miles from the sun, and 50 millions beyond the orbit of the Earth. Next to the orbit of Mars are four small planetary bodies, sometimes named *Asteroids*, which were discovered at different times about the beginning of the present century. They are named Vesta, Juno, Ceres, and Pallas. Of these, the first in order from the sun is Vesta, at the distance of 225 millions of miles; the next, Juno, at the distance of 253 millions. Ceres, at 260 millions; and Pallas, at 266 millions of miles. The planet Jupiter is the next in order, and performs its revolution in an orbit 495 millions of miles from the sun, and 400 from the orbit of the earth. Saturn is nearly double the distance of Jupiter from the sun, being distant from that orb above 900 millions of miles. The most distant planet in the system which has yet been discovered is Uranus, or Herschel, which is removed from the sun at more than double the distance of Saturn; namely, above 1800 millions of miles. The orbit of this planet includes the orbits of the whole of the bodies of the solar system that have hitherto been discovered, and is eleven thousand three hundred millions of miles in circumference, and three thousand six hundred millions in diameter. To move round this circumference at the rate of thirty miles every hour would require above forty-two thousand nine hundred years. Such is the order, and such are the ample dimensions of that system of which we form a part; and yet it is but a mere speck in the map of the universe. The following diagram exhibits the order of the planets in the solar system.

In the following figure the small central star represents the sun, and the circles represent the orbits of Mercury, Venus, the Earth, Mars, Vesta, Juno, Ceres, Pallas, Jupiter, Saturn, and Uranus, in the order here enumerated. The orbits of the new planets, Vesta, Juno, Ceres, and Pallas, are represented as crossing each other, as they do in nature; and the portion of a long ellipse which crosses the orbits of

* A *fac-simile* of one of the letters of Copernicus may be seen in No. IX. of the "Edinburgh Philosophical Journal" for July, 1821; and an engraving of the house in which he lived in No. XIII. of the same Journal for July, 1822

*Fig. 5.*

all the planets represents the orbit of a comet. The *proportional distances* and *magnitudes* of the planets are represented in a subsequent chapter.

I shall now proceed to offer a few arguments or demonstrations of the truth of the solar system, as first proposed by Copernicus, and now received by all astronomers. I shall first state those which may be called presumptive arguments, or which amount to a high degree of probability, and then briefly illustrate those which I consider as demonstrative. Having already endeavoured to prove the diurnal rotation of the earth, I shall consider that point as settled, and confine myself, at present, to the consideration of the earth's *annual revolution*, and the phenomena of the planets which result from this motion.

The presumptive arguments that the earth is a planetary body, and revolves round the sun in concert with other planets, are, 1. *It is most simple and agreeable to the general arrangements of the Creator* that such an order as we have now stated should exist in the planetary system. For, by the motion of the earth, all the phenomena of the heavens are resolved and completely accounted for, which they cannot be on any other system, without the supposition of clumsy and complex machinery and motions altogether repugnant to reason and to what we know of the other operations of the all wise Creator. Besides, it is contrary to the first rule laid down in philosophy—"That more causes of natural things are not to be admitted than are both true and sufficient to explain the phenomena." But the Ptolemaic, or vulgar system of the world, assumes the existence of facts which can never be established, and introduces cumbrous and complicated motions which are quite unnecessary for explaining the phenomena. 2. Because *it is more rational to suppose that the earth moves about the sun, than that the huge masses of the planets*, some of which are a thousand times larger than our globe—or that the stupendous body of the sun, which is thirteen hundred thousand times greater—*should perform a revolution around so comparatively small a globe as the earth.* To suppose the contrary, would be repugnant to all the laws of motion that are known to exist in the universe. We might as well expect that a sling, which contains a millstone in it, may be fastened to a pebble, and continue its motion about that pebble without removing it, as that the sun can revolve about the earth while the earth continues immovable in the centre of that motion.

3. It was a law discovered by Kepler, by which all the planets, both primary and secondary, are regulated, "That the squares of the periodic times of the planets' revolutions are as the cubes of their distances;"* but, if the sun move around the earth, that law, which is established on the most accurate observations, is completely destroyed, and the general order and symmetry of the system of nature are infringed upon and interrupted. For, according to that law, the sun would be so far from revolving about the earth in 365 days, that it would require no less than 589 years to accomplish one revolution, as will appear from the following calculation: The moon revolves round the earth in twenty-seven days eight hours, at the distance of 240,000 miles; the sun is placed at the distance of 95,000,000 miles. The period of the revolution of any body revolving at that distance will be found, according to the law now stated, by the following proportion: As the cube of the moon's distance : is to the cube of the sun's distance : : so is the square of the moon's period : to the square of the period of any body moving about the earth at the distance of the sun. Now, the cube of the

* For example; if one planet were four times as distant as another, it would revolve in a period eight times as long; for the cube of $4=64$ is equal to the square of 8. Thus Mars is about four times as remote from the sun as Mercury, and Uranus four times as remote as Jupiter, and their periods of revolution correspond to this proportion of their distances. This argument, when properly understood, is demonstrative.

moon's distance, 240,000, is 13,824,000,000 000,000; the cube of the sun's distance, 95, 000,000, is 857,375,000,000,000,000,000,000. The square of the moon's periodical time, twenty-seven days eight hours, is 747, which, multiplied by the cube of the sun's distance, and divided by the cube of the moon's distance, is 46,329,508,463, the square root of which is 215,242 days, or 589 years and 257 days. This calculation is of itself sufficient to determine the point in question, for there is no exception known to the law we have stated. Besides, did the sun observe this universal law, and yet revolve in 365 days, his distance ought to be only about 1,351,000 miles, whereas it can be shown that it is about 95, 000,000. For, as the square of the moon's period, 747 : is to the square of the sun's, 365 $\times$365=133,225 : : so is the cube of the moon's distance from the earth 13,824,000, 000,000,000 : to 2,465,465,050,240,963,855, the cube root of which is 1,351,295, or one million, three hundred and fifty-one thousand, two hundred and ninety-five miles, which should be the sun's distance if he revolved about the earth in accordance with this universal law, which governs every moving body, both primary and secondary.*

4. It appears most reasonable to conclude that the sun is placed near the centre of the planetary system, as it is the fountain of light and heat for cheering and irradiating all the worlds within the sphere of its influence; and it is from the centre alone that these emanations can be distributed in uniform and equable proportions to all the planets. If the earth were in the centre, with the sun and planets revolving around it, the planetary worlds would be, at different times, at very different distances from the sun; and, when nearest to him, would be scorched with excessive heat, and at their greatest distance would be frozen with excessive cold; and as some of the planets would, on this supposition, be sometimes five times the distance from the source of light and heat which they are at other times, it would produce the same effect as if the earth were occasionally to be carried beyond the orbit of Jupiter, four hundred and seventy millions of miles from its present position. But if the sun be considered as placed in the centre of the system, we have then presented to our view a system of universal harmony and order: the planets all revolving around the great central orb by the universal law or power of gravitation, and every thing corresponding to the laws of circular motion and central forces; otherwise we are left entirely in the dark as to the operations of nature and the system of the universe.

There is no more difficulty in conceiving the earth to move than that it should remain quiescent in the same place. For if the earth remain at rest in the centre of the system, it is supported upon nothing, in the midst of infinite space, by the power of Omnipotence: and we have as little conception how a ponderous globe of the size of the earth should remain suspended upon *nothing*, as that it should move through the voids of space with a velocity of sixty-eight thousand miles an hour. The Power that is able to suspend it in empty space can as easily make it fly through the ethereal regions, as is the case with Jupiter and Saturn, which are globes a thousand times larger; and such a motion is *necessary* in order to display the harmony and proportion of the Creator's works, and to vindicate his all-perfect wisdom and intelligence. It is even no more difficult to conceive such a motion than it is to conceive how the earth can be inhabited all around, and that there can be no such thing as *up* or *down* in the universe, absolutely considered; how, for example, persons can stand upright on the opposite sides of the globe; that our antipodes, standing with their heads in an opposite direction to ours can look *up* to the sky and *down* to the earth just as we do, without any more danger of falling off from its surface than we are in of being carried upward into the air. These are circumstances which necessarily flow from the rotundity of the earth and its attractive power; they are known to every one, and cannot possibly be disputed, unless we deny the globular form of the earth, or, in other words, contradict the evidence both of our reason and our senses. But we know as little of that power which draws every thing to the earth on all sides, as we do of a power which carries a planet round its orbit at the rate of a hundred thousand miles an hour. Both are effects of that Almighty agent who contrived the universe, "who is wonderful in counsel and excellent in working," and "whose ways," in numerous instances, "are past finding out." But, in all cases where the least doubt exists, we ought to adopt that view of the Creator's plans and operations which is most consistent with the ideas of a Being of infinite perfection.

The arguments now stated, although we could produce no other, would be sufficient to corroborate the idea that the earth is a planetary body, performing its motion through the depths of space; but, happily, we are able to produce proofs of the sun occupying the centre of the system, which may be considered as demonstrative. Those proofs I shall now state as briefly as possible.

* The *primary* planets are those which revolve about the sun as their centre, as Venus, Mars, and Jupiter. The *secondary* planets are those which revolve around the primary, as the moons of Jupiter, Saturn, and Uranus.

1. In the first place, the planets Mercury and Venus are uniformly observed to have two conjunctions with the sun, but no opposition, which could not possibly happen unless the orbits of those planets lay *within* the orbit of the earth, as delineated in the plan of the solar system. This circumstance will be more particularly understood by the following diagram.

Fig. 6.

Let $S$ represent the sun in the centre of the system; $M$, Mercury; $V$, Venus; $E$, Earth; and $G$, Mars. It is evident, that when Mercury is at $M$ and Venus at $V$, they will be seen from the earth, $E$, in the same part of the heavens as the sun; namely, at $B$, where Mars is represented; because they are all situated in the same straight line, $E$ $B$. In this position they are between the sun and the earth, and this is called their *inferior* conjunction. Again, when Mercury and Venus come to the situations $H$, $K$, they are again in the straight line joining the centres of the earth and sun, and are therefore seen in the same part of the heavens with that orb. In these last positions they are *beyond* the sun, which is now between them and the earth. This is called their *superior* conjunction. Here it is evident that these two planets must appear twice in conjunction with the sun, in each revolution, to a spectator on the earth at $E$; but they can never appear *in opposition* to the sun, or, in other words, they can never be seen in the east immediately after the sun has set in the west, as is the case with Mars, which may be seen at $G$ when the sun appears at $B$, in the opposite direction; all which appearances are exactly correspondent with observation, but could never take place if the earth were the centre of their motions.

2. The greatest *elongation* or distance of Mercury from the sun is twenty-nine degrees, and that of Venus about forty-seven degrees, which answers exactly to observation, and to the positions and distances assigned to them in the system; but if they moved round the earth as a centre, they would sometimes be seen 180 degrees from the sun, or *in opposition* to him. But they have never been seen in such a position by any observer, either in ancient or modern times, nor at greater distances from the sun than those now specified. It is evident, from the figure, that when Venus is at $D$, the point of its greatest elongation, it will be seen at $a$, in the direction of $E$ $a$, which forms an angle of forty-seven degrees with the line $E$ $B$, or the direction of the sun as seen from the earth. In like manner Mercury, when at its greatest elongation, at $R$, will be seen at $e$, which forms a less angle than the former with the line of direction in which the sun is seen. Hence it is that Mercury is so rarely seen, and Venus only at certain times of the year; whereas, were the earth at rest in the centre of the planetary orbits, these planets would be seen in all positions and distances from the sun in the same manner as the moon appears.

3. The planets Mars, Jupiter, Saturn, Uranus, and all the other superior planets, have each their *conjunctions* and *oppositions* to the sun, alternate and successively, which could not be unless their orbits were *exterior* to the orbit of the earth. Thus, from the earth at $E$ Mars will appear in conjunction with the sun at $B$ and in opposition at $G$; that is, in a part of the heavens 180 degrees distant from the sun, or directly opposite to him; and the same is the case with all the planets beyond the orbit of Mars, which proves that they are all situated in orbits which *include* the orbit of the earth.

4. In the arrangements of the planets in the system, as formerly stated, they will all be sometimes much nearer to the earth than at other times; and, consequently, their brightness and splendour, and likewise their *apparent diameters*, will be proportionably greater at one time than at another. This corresponds with every day's observation. Thus the apparent diameter of Venus, when greatest, is fifty-eight seconds, and when least, about ten seconds; of Mars, when greatest about twenty-five seconds, and when least, not above four or five seconds; so that in one part of his

orbit he is five times nearer to the earth than at the opposite part, and, consequently, appears twenty-five times larger in surface. Thus, when Mars is in the point *G*, in opposition to the sun, he is the whole diameter of the earth's orbit, or 190 millions of miles nearer us than when he is in conjunction, in the point *B*. In the one case he is only 50 millions of miles distant from the earth, while in the other he is no less than 240 millions of miles; and his apparent magnitude varies accordingly. But, according to the system which places the earth in the centre, the apparent magnitude of Mars, and of all the other planets, should always be equal, in whatever points of their orbits they may be situated.

5. When the planets are viewed through good telescopes, they appear with different phases; that is, with different parts of their bodies enlightened. Thus, Mars sometimes appears round, or with a full enlightened face; and at other times he presents a gibbous phase, like that of the moon three or four days before the full. Venus presents all the different phases of the moon, appearing sometimes with a gibbous phase, sometimes like a half moon, and at other times like a slender crescent. Thus, at *V*, her dark side is turned to the earth, and she is consequently invisible, unless she happens to pass across the disk of the sun, when she appears like a round black spot on the surface of that luminary. At *D* she appears like a crescent; at *A* like a half moon, because only the one half of her enlightened side is turned towards the earth; and at *F* she presents a gibbous phase. When Copernicus first proposed his system, it was one of the strongest objections which his adversaries brought against it, and by which they supposed they had completely confuted him; namely, that "if his hypothesis were true, Venus and Mercury must vary their phases like the moon, but that they constantly appeared round." Copernicus at once admitted that these consequences were justly drawn; and he attributed the cause of their round appearances to the structure of our eyes, to the distance of the objects, and to those radiating crowns which hinder us from judging either of the size or the exact form of the stars and planets; and he is said to have prophesied that one day or other these various phases would be discovered; and little more than half a century intervened, when the telescope (which was unknown in the time of Copernicus), in the hands of Galileo, determined to a certainty the matter in dispute, and confirmed the prediction of that eminent astronomer. How great, may we suppose, would have been the transport of that illustrious man had a telescope been put into his hands, and had he seen, as we now do, that Venus, when she appears most brilliant, exhibits, in reality, the form of a crescent! so that this formidable objection to the truth of his system has now become one of the strongest and most palpable demonstrations of the reality of that arrangement which has placed the sun in the centre, and set the earth in motion between Mars and Venus.

6. All the planets in their motions are seen sometimes to move *direct;* sometimes *retrograde;* and at other times to remain *stationary*, without any apparent motion: in other words, in one part of their course they appear to move to the *east;* in another part to the *west;* and at certain points of their orbit they appear fixed for some time in the same position. Thus, Venus, when she passes from her greatest elongation westward, at *L*, to her elongation eastward, at *D*, through the arch *L C K F A D*, will appear *direct* in motion, or from west to east; but as she passes from *D* to *L*, through the arch *D V L*, she will appear *retrograde*, or as if she were moving from east to west. When she is in those parts of her orbit most distant from the sun, as at *D* and *L*, she will appear for some time stationary, because the tangent line or visual ray appears to coincide for some time with the orbit of the planet; just as a ship at a great distance, when moving directly towards the eye in the line of vision, appears for a little time to make no progress. All these apparent diversities of motion are *necessary* results of the Copernican system, and they coincide with the most accurate observations; but they are altogether inexplicable on any other hypothesis.

7. The planets Mercury and Venus, in their superior conjunctions with the sun, as at *H* and *K*, are sometimes hid behind the sun's body; which could never happen on the Ptolemaic hypothesis, because in it the orbit of the sun is supposed to be *exterior* to the orbits of these two planets.

8. The *times* in which these conjunctions, oppositions, direct and retrograde motions, and stationary aspects of the planets happen, are not such as they would be if the earth were at rest in its orbit; but *precisely* such if the earth move, and all the other planets in the periods assigned them. Thus, suppose Venus at any time in conjunction with the sun at *V*; were the earth at rest in *E*, the next conjunction of the same kind would happen again when Venus had made just one revolution, that is, in 224 days. But this is contrary to experience; for a much longer time is found to intervene between two conjunctions of the same kind, as must be if we suppose the earth to have a motion in the same direction. For, when Venus comes to the point *V*, the earth will have passed in that time from *E* to some

other part of its orbit, and from this part still keeps moving on till Venus overtakes it, and gets again between it and the sun. The period which Venus will take before she overtakes the earth and comes in conjunction with the sun, is found as follows: The daily mean motion of the earth is fifty-nine minutes eight seconds (which is the same as the *apparent* mean motion of the sun), and the daily mean motion of Venus is one degree, thirty-six minutes, eight seconds. The difference of these mean motions is thirty-seven minutes. Therefore, as 37′: is to the number of minutes in the whole circle of 360 degrees, namely, 21600′:: so is one day: to 583 days, 18 5-4 hours, which is the time between two conjunctions of the same kind, or one year and a little more than seven months, which is somewhat more than two and a half revolutions of Venus, and which perfectly agrees with the most accurate observations.

In the last place, if we were to suppose the earth at rest in the centre of the planetary system, *the motions of all the planets would present a scene of inextricable confusion.* They would appear so irregular and anomalous that no rational being would ever suppose they could be the contrivances of an all-wise Being, possessed of every perfection. This will appear at once by casting the eye on Fig. 7, which represents the apparent motion of the planet Mercury, as seen from the earth, from the year 1708 to 1715, as originally delineated by the celebrated astronomer Cassini, and published in the Memoirs of the Royal Academy of Sciences. Here the motion of this planet appears to describe a complicated curve, or a series of loops or spirals running into each other, instead of a regular circular motion in an orbit; and such irregular curves must be the *real* motion of the planet, to account for all its appearances, if the earth were considered as remaining fixed in the centre of its motion. On each side of the loops in the figure it appears stationary; in that part of the loop next the earth it appears retrograde; and in all the rest of the path, which seems to stretch far away from the earth, it appears direct, till its course again appears to run into a loop. Let the reader trace the whole of the curve here delineated, and then ask himself whether such motions can possibly be real, or the contrivances of Infinite Wisdom. The motions of Venus, and of all the superior planets, as seen from the earth, present similar curves and anomalies. Now it is a fact, that when the earth is considered as moving round the sun in a year, between the orbits of Venus and Mars, all these apparent irregularities are completely accounted for by the combination of motions produced by our continual change of position, in consequence of the earth's progress in its annual orbit; and thus the movements of all the planets are reduced to perfect harmony and order.

Fig. 7.

Such is a brief summary of the leading proofs which may be brought forward to establish the fact of the annual motion of the earth round the sun. They all converge towards the same point, and hang together in perfect harmony. It is next to impossible that such a combination of arguments could be found to prove a false position. When thoroughly understood and calmly considered, they are calculated to produce on the mind of every unbiassed inquirer as strong a conviction of the point in question, as if, from a fixed position in the heavens, we actually beheld the earth and all its population sweeping along through the ethereal spaces with the velocity of sixty-eight thousand miles every hour. These arguments are plain and easy to be understood if the least attention be bestowed. Most of them require nothing more than common observation, or, in other words, common sense,

in order to understand and appreciate them; and he who will not give himself the trouble to weigh them with attention must be contented to remain in ignorance. I have stated them with more particularity than is generally done in elementary books on this subject, because they lie at the foundation of astronomical science, and of all our views of the amplitude and order of the universe: and because many profess to believe in the motion of the earth merely on the authority of others, without examining the grounds of their belief, and, consequently, are never fully and rationally convinced of the important position to which we have adverted.

The motion of the earth presents before us *a most sublime and august object of contemplation.* We wonder at beholding a steam carriage, with all its apparatus of wagons and passengers, carried forward on a railway at the rate of thirty miles an hour, or a balloon sweeping through the atmosphere with a velocity of sixty miles in the same time. Our admiration would be raised still higher, should we behold Mount Etna, with its seventy cities, towns, and villages, and its hundred thousand inhabitants, detached from its foundations, carried aloft through the air, pouring forth torrents of red-hot lava, and impelled to the continent of America in the space of half an hour. But such an object, grand and astonishing as it would be, could convey no adequate idea of the grandeur of such a body as the earth flying through the voids of space in its course round the sun. Mount Etna, indeed, contains a mass of matter equal to more than 800 cubical miles, but the earth comprises an extent of more that 263,000,000,000 of solid miles, and, consequently, is more than three hundred millions of times larger than Etna, and of a much greater density. The comparative size of this mountain to the earth may be apprehended by conceiving three hundred millions of guineas laid in a straight line, which would extend 4700 miles, or from London to the equator or to South America. The whole line of guineas throughout this vast extent would represent the bulk of the earth, and a single guinea, which is only about an inch in extent, would represent the size of Etna compared with that of the earth. Again: Etna, in moving from its present situation to America in half an hour, would move only at the rate of 130 miles in a minute; while the earth in its annual course flies with a velocity of more than 1130 miles in the same space of time, or about nine times that velocity.

How august, then, and overpowering the idea, that during every pulse that beats within us we are carried nearly twenty miles from that portion of absolute space we occupied before! that during the seven hours we repose in sleep, we, and all the inhabitants of the world, are transported 470,000 miles through the depths of space; that during the time it would take to read deliberately from the beginning of the last paragraph to the present sentence we have been carried forward with the earth's motion more than 4500 miles; and that, in the course of the few minutes we spend in walking a mile, we are conveyed through a portion of absolute space to the extent of more than 18,000 miles. What an astonishing idea does such a motion convey of the ENERGIES of the Almighty Creator, especially when we consider that thousands of rolling worlds, some of them immensely larger than our globe, are impelled with similar velocities, and have, for many centuries past, been running without intermission their destined rounds! Here, then, we have a magnificent scene presented to view, far more wonderful than all the enchanted palaces rising and vanishing at the stroke of the magician's rod, or all the scenes which the human imagination has ever created, or the tales of romance have recorded, which may serve to occupy our mental contemplation when we feel *ennui*, or are at a loss for subjects of amusement or reflection. We may view in imagination this ponderous globe on which we reside, with all its load of continents, islands, oceans, and its millions of population, wheeling its course through the heavens at a rate of motion, *every day*, exceeding 1,600,000 miles; we may transport ourselves to distant regions, and contemplate globes far more magnificent, moving with similar or even greater velocities; we may wing our flight to the starry firmament, where worlds unnumbered run their ample rounds, where suns revolve around suns, and systems around systems, around the throne of the Eternal; till, overpowered with the immensity of space and motion, we fall down with reverence, and worship HIM who presides over all the departments of universal nature, "who created all worlds, and for whose pleasure they are and were created."

## CHAPTER III.

*On the Magnitudes, Motions, and other Phenomena of the bodies connected with the Solar System.*

In the elucidation of this subject I shall, in the first place, present a few sketches of the magnitudes, motions, and other phenomena of the primary planets belonging to the solar system. These planets, as formerly stated, are, Mercury, Venus, Mars, Vesta, Juno, Ceres, Pallas, Jupiter, Saturn, and Uranus, which are here mentioned in the order of their distance from the sun.

In this order I shall proceed to give a few descriptions of the principal facts which have been ascertained respecting each planet.

### I. THE PLANET MERCURY.

This planet is the nearest to the sun of any that have yet been discovered, although a space of no less than thirty-seven millions of miles intervene between Mercury and the central luminary. Within this immense space several planets may revolve, though they may never be detected by us, on account of their proximity to the sun. To an inhabitant of Mercury, such planets, if any exist, may be as distinctly visible as Venus and Mercury are to us; because they will appear, in certain parts of their course, at a much greater elongation from the sun than they can to us. This planet, on account of its moving in the neighbourhood of the sun, is seldom noticed by a common observer. It is only to be seen by the naked eye about the period of its greatest elongation from the sun, which is sometimes only about 16° or 17°, and never exceeds 29°. These elongations happen, at an average, about six or seven times every year; about three times when the planet is eastward of the sun, and three times when it is to the westward. This planet, therefore, can only be seen by the unassisted eye for a few days about these periods, either in the morning a little before sunrise, or in the evenings a little after sunset. As it is sometimes not above 16°, even at its greatest elongation, from the point of sunrise or sunset, and is likewise very near the horizon, it is sometimes very difficult to distinguish it by the naked eye, and at all other times it is generally imperceptible without a telescope. It is said that the celebrated astronomer Copernicus had never an opportunity of seeing this planet during the whole course of his life. I have seen Mercury three or four times with the naked eye, and pretty frequently with a telescope. With a magnifying power of 150 times I have seen it about the time of its greatest elongation, more than half an hour after sunrise, when it appeared like a small brilliant half moon; but no spots could be discovered upon it. To the naked eye, when it is placed in a favourable position, it appears with a brilliant white light, like that of Venus, but much smaller and less conspicuous. The best mode of detecting it is by means of an equatorial telescope, which, by a slight calculation and the help of an ephemeris, may be directed to the precise point of the heavens where it is situated. The most favourable seasons of the year for observing it are when its greatest elongations happen in the month of March or April, and in August or September. In winter it is not easily perceived, on account of its very low altitude above the horizon at sunrise and sunset; and in summer, the long twilight prevents our perception of any small object in the heavens. From the planets Saturn and Uranus, Mercury would be altogether invisible, being completely immersed in the splendour of the solar rays; so that an inhabitant of these planets would never know that such a body existed in the universe, unless he should happen to see it when it passed, like a small dark point, across the disk of the sun.

Mercury revolves around the sun in the space of eighty-seven days twenty-three hours, which is the length of its year; but the time from one conjunction to the same conjunction again is about 116 days; for as the earth has moved about a fourth part of its revolution during this period, it requires nearly thirty days for Mercury to overtake it, so as to be in a line with the sun. During this period of about 116 days it passes through all the phases of the moon, sometimes presenting a gibbous phase, sometimes that of a half moon, and at other times the form of a crescent; which phases and other particulars will be more particularly explained in the description I shall give of the planet Venus. Mercury, at different times, makes a transit across the sun's disk; and as its dark side is then turned to the earth, it will appear like a round spot upon the face of the sun; and when it passes near the centre of the sun it will appear for

the space of from five to seven hours on the surface of that orb. Its last transit happened on the 7th of November, 1835, which was visible in the United States of America, but not in Britain, as the sun was set before its commencement. The next transits, to the end of the present century, are as follow:

| | hours. | minutes. | |
|---|---|---|---|
| 1845, May 8th | 7 | 54 | P.M. |
| 1848, November 9th | 1 | 38 | P.M. |
| 1861, November 12th | 7 | 20 | P.M. |
| 1868, November 5th | 6 | 44 | A.M. |
| 1878, May 6th | 6 | 38 | P.M. |
| 1881, November 8th | 0 | 40 | A.M. |
| 1891, May 10th | 2 | 45 | A.M. |
| 1894, November 10th | 6 | 17 | P.M. |

The time stated in the above table is the mean time of conjunction at Greenwich, or nearly the middle of the transit; so that, in whatever part of the world the sun is risen at that time, the transit will be visible if no clouds interpose. The next two transits, in 1845 and 1848, will be partly visible in Britain.

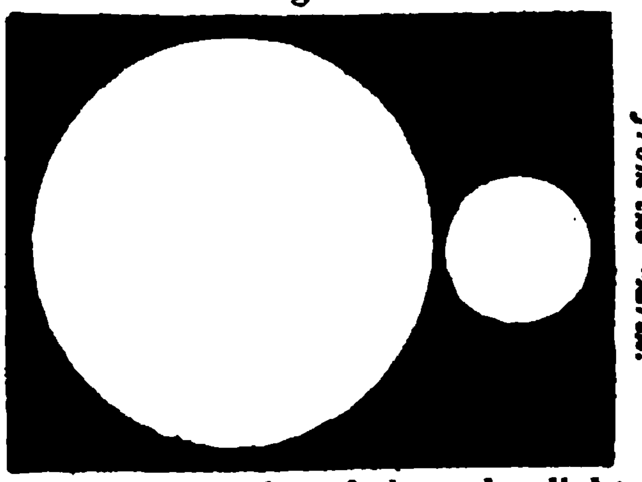
Few discoveries have been made on the surface of this planet by means of the telescope, owing to the dazzling splendour of its rays, which prevents the telescope from presenting a well defined image of its disk; owing, likewise, to the short interval during which observations can be made, and particularly to its proximity to the horizon, and the undulating vapours through which it is then viewed. That unwearied observer of the heavens, Sir William Herschel, although he frequently viewed this planet with magnifying powers of 200 and 300 times, could perceive no spots or any other phenomenon on its disk from which any conclusions could be deduced respecting its peculiar constitution or the period of its rotation. Mr. Schroeter, an eminent German astronomer, however, appears to have been more successful. This gentleman has long been a careful observer of the phenomena of the planetary system, by means of telescopes of considerable size, and has contributed not a few interesting facts to astronomical science. He assures us that he has seen not only spots, but even mountains on the surface of Mercury, and that he succeeded in ascertaining the altitude of two of these mountains. One of them he found to be little more than 1000 toises in height, or about an English mile and 372 yards. The other measured 8900 toises, or ten miles and 1378 yards, which is more than four times higher than Mount Etna or the Peak of Teneriffe. The highest mountains are said to be situated in the southern hemisphere of this planet. The same observer informs us, that, by examining the variation in the daily appearance of the horns or cusps of this planet, when it appeared of a crescent form, he found the period of its diurnal rotation round its axis to be twenty-four hours, five minutes, and twenty-eight seconds. But these deductions require still to be confirmed by future observations.

The light or the intensity of solar radiation which falls on this planet is nearly seven times greater than that which falls upon the earth; for the proportion of their distances from the sun is nearly as three to eight, and the quantity of light diffused from a luminous body is as the square of the distance from that body. The square of 3 is 9, and the square of 8, 64, which, divided by 9, produces a quotient of 7 1-9, which nearly expresses the intensity of light on Mercury compared with that on the earth. Or, more accurately, thus: Mercury is 36,880,000 of miles from the sun, the square of which is 1,360,134,400,000,000: the earth is distant 95,000,000, the square of which is 9,025,000,000,000,000. Divide this last square by the first, and the quotient is about 6⅔, which is very nearly the proportion of light on this planet. As the apparent diameter of the sun is likewise in proportion to the square of the distance, the inhabitants of this planet will behold in their sky a luminous orb, giving light by day, nearly seven times larger than the sun appears to us; and every object on its surface will be illuminated with a brilliancy seven times greater than are the objects around us in a fine summer's day. Such a brilliancy of lustre on every object would completely dazzle our eyes in their present state of organization; but in every such case we are bound to believe that the organs of vision of the inhabitants of any world are exactly adapted to the sphere they occupy in the system to which they belong. Were we transported to such a luminous world as Mercury, we could perceive every object with the same ease and distinctness we now do, provided the pupil of the eye, instead of being one eighth of an inch in diameter, as it now is, were contracted to the size of one fiftieth of an inch. In consequence of the splendour which is reflected from every object on this planet, it is likely that the whole scenery of nature will assume a most glorious and magnificent aspect, and that the *colours* depicted on the various parts of the scenery of that world will be much more *vivid* and *splendid* than they appear on the scenery of our terrestrial mansion; and since it appears highly probable that there are elevated mountains on this planet, if they be adorned with a diversity of colour, and of rural and artificial objects, they must present to the beholder a most beautiful, magnificent, and sublime appearance. The following figures will present to the eye a comparative view of the apparent size of the

sun, as beheld from Mercury and from the earth.

Fig. 8.

Diameter of the Sun as seen from Mercury.



Diameter of the Sun as seen from the Earth.

While the intensity of the solar light on this planet is about seven times greater than on the earth, the light on the surface of Uranus, the most distant planet of the system, is 360 times less than that on the earth; for the square of the earth's distance, as formerly stated, is 9,025,000,000,000,000, and the square of the distance of Uranus from the sun, 1,800,000,000, of miles, is 3,240,000,000,000,000,000, which, divided by the former number, gives a quotient of 359 and a fraction, or, in round numbers, 360; the number of times that the light on the earth exceeds that on Uranus. Yet we find that the light reflected from that distant planet, after passing 1,800,000,000 of miles from the body of the sun, and returning again by reflection 1,700,000,000 of miles to the earth, is visible through our telescopes, and even sometimes to the naked eye. Thus it appears that the intensity of light at the two extremes of the solar system is in the proportion of 2400 to 1; for $360 \times 6\frac{2}{3} = 2400$, the number of times that the quantity of light on Mercury exceeds that on Uranus. But we may rest assured, from what we know of the plans of Divine wisdom, that the eyes of organic intelligence, both at the extremes and in all the intermediate spaces of the system, are exactly adapted to the sphere they occupy and the quantity of light they receive from the central luminary.

In regard to the *temperature* of Mercury, if the intensity of *heat* were supposed to be governed by the same law as the intensity of light, the heat in this planet would, of course, be nearly seven times greater than on the earth. Supposing the average temperature of our globe to be fifty degrees of Fahrenheit's thermometer, the average temperature on Mercury would be 333 degrees, or 121 degrees above the heat of boiling water; a degree of heat sufficient to melt sulphur, to make nitrous acid boil, and to dissipate into vapour every volatile compound. But we have no reason to conclude that the degree of sensible heat on any planet is in an inverse proportion to its distance from the sun. We have instances of the contrary on our own globe. On the top of the highest range of the Andes, in South America, there is an intense cold at all times, and their summits are covered with perpetual snows, while in the plains immediately adjacent the inhabitants feel all the effects of the scorching rays of a tropical sun. The sun, during our summer in the northern hemisphere, is more than three millions of miles further from us than in winter; and although the obliquity of his rays is partly the cause of the cold felt in winter when he is nearest us, yet it is not the *only* cause; for we find that the cold in New York and Pennsylvania is more intense in winter than in Scotland, although the sun rises from ten to sixteen degrees higher above the horizon in the former case than in the latter. Besides, we find that the heat of summer in the southern hemisphere, *when the sun is nearest to the earth*, is not so great as in the summer of corresponding latitudes in the northern hemisphere. In short, did heat depend chiefly on the nearness of the sun or the obliquity of his rays, we should always have the same degree of heat or cold at the same time of the year, in a uniform circle; which experience proves to be contrary to fact. The degree of heat, therefore, on any planet, and on different portions of the same planet, must depend in part, and perhaps chiefly, on the nature of the atmosphere, and other circumstances connected with the constitution of the planet, in combination with the influence of the solar rays. These rays undoubtedly produce heat, but the degree of its intensity will depend on the nature of the substances on which they fall; as we find that the same degree of sensible heat is not felt when they fall on a piece of iron or marble as when they fall on a piece of wood or flannel.

Mercury was long considered as the smallest primary planet in the system; but the four new planets lately discovered between the orbits of Mars and Jupiter are found to be smaller. Its diameter is estimated at 3200 miles, and, consequently, its surface contains above 32,000,000 of square miles, and its solid contents are 17,157,324,800, or more than seventeen thousand millions of solid miles; and if the number of solid miles contained in the earth, which are 264,000,000,000, be divided by this sum, the quotient will be somewhat more than fifteen, showing that the earth is above fifteen times larger than Mercury. Notwithstanding the comparatively diminutive size of this planet, it is capable of containing a population upon its surface much greater than has ever been supported on the surface of the earth during any period of its history. In making an estimate on this point, I shall take the population of England as a standard. England contains 50,000 square miles of surface, and 14,000,000

of inhabitants, which is 280 inhabitants for every square mile. The surface of Mercury contains 32,000,000 of square miles, which is not much less than all the habitable parts of our globe. At the rate of population now stated, it is sufficiently ample to contain 8,960, 000,000, or eight thousand nine hundred and sixty millions of inhabitants, which is more than eleven times the present population of our globe. And although the one half of the surface of this planet were to be considered as covered with water, it would still contain nearly six times the population of the earth. Hence it appears, that small as this planet may be considered when compared with others, and seldom as it is noticed by the vulgar eye, it in all probability holds a far more distinguished rank in the intellectual and social system under the moral government of God, than this terrestial world of which we are so proud, and all the living beings which traverse its surface.

I shall only mention further the following particulars in reference to this planet. In its revolution round the sun, its motion is swifter than that of any other planet yet discovered; it is no less than at the rate of 109,800 miles every hour at an average, although in some parts of its course it is slower, and in other parts swifter, since it moves in an elliptical orbit. Of course it flies 1830 miles every minute, and more than thirty miles during every beat of our pulse. The *density* of this planet is found by certain physical calculations and investigations, founded on the laws of universal gravitation to be nine times that of water, or equal to that of lead; so that a ball of lead 3200 miles in diameter would exactly poise the planet Mercury. This density is greater than that of any of the other planets, and nearly twice the density of the earth. The *mass* of this planet, or the *quantity of matter* it contains, when compared with the mass of the sun, is, according to La-Place, as 1 to 2,025,810, or about the two millionth part; that is, it would require two millions of globes of the size and density of Mercury to weigh one of the size and density of the sun. But as Mercury contains a much greater quantity of matter in the same bulk than the sun, *in point of size* it would require 22,000,000 of globes of the bulk of Mercury to compose a body equal to that of the sun. In consequence of the great density of this planet, bodies will have a greater weight on its surface than on the earth. It has been computed, that a body weighing one pound on the earth's surface would weigh one pound eight and a half drachms on the surface of Mercury. If the centrifugal force of this planet were suspended, and its motion in a circular course stopped, it would fall towards the sun, as a stone when thrown upward falls to the ground, by the force of gravity, with a velocity continually increasing as the square of the distance from the sun diminished. The time in which Mercury or any other planet would fall to the sun by the centripetal force, or the sun's attraction, is equal to its periodic time divided by the square root of thirty-two; a principle deduced from physical and mathematical investigation. Mercury would therefore fall to the sun in 15 days, 13 hours; Venus in 39 days, 17 hours; the earth in 64 days, 13 hours; Mars in 121 days, 10 hours; Vesta in 205 days; Ceres in 297 days, 6 hours; Pallas in 301 days, 4 hours; Juno in 354 days, 19 hours; Jupiter in 765 days, 19 hours, or above two years; Saturn in 1901 days, or about five years; Uranus in 5425 days, or nearly fifteen years; and the Moon would fall to the earth, were its centrifugal force destroyed, in 4 days, 20 hours. Some of the deductions stated above may be apt to startle some readers as beyond the powers of limited intellects, and above the range of human investigation. The discoveries of Newton, however, have now taught us the laws by which these bodies act upon one another; and as the effects they produce depend very much upon the quantities of matter they contain, by observing these effects we are able, by the aid of mathematical reasoning, to determine the quantities of matter in most of the planets with considerable certainty. But to enter on the demonstration of such points would require a considerable share of attention and of mathematical knowledge, and would probably prove tedious and uninteresting to the general reader.

Mercury revolves in an orbit which is elliptical, and more eccentric than the orbits of most of the other planets, except Juno, Ceres, and Pallas. Its *eccentricity*, or the distance of the sun from the centre of its orbit, is above 7,000,000 of miles. The time between its greatest elongations from the sun varies from 106 to 130 days. Its orbit is inclined to the ecliptic, or the plane of the earth's orbit, in an angle of seven degrees, which is more than double the inclination of the orbit of Venus.

## II. OF THE PLANET VENUS.

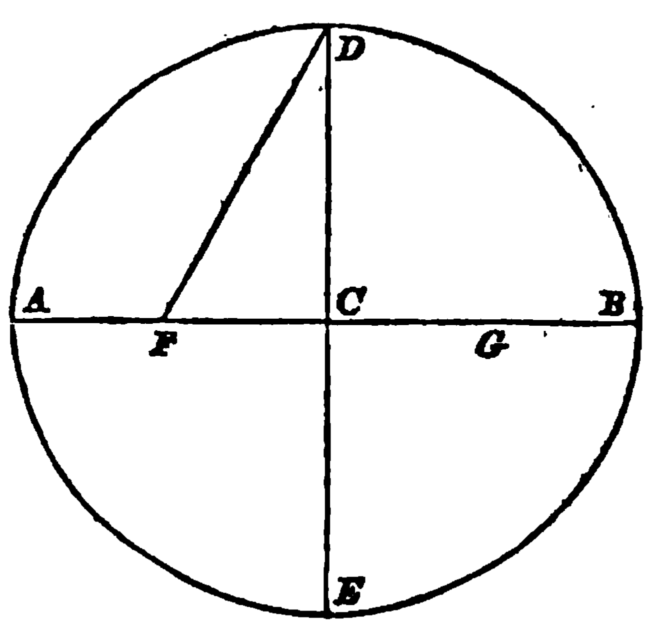
Of all the luminaries of heaven, the sun and moon excepted, the planet Venus is the most conspicuous and splendid. She appears like a brilliant lamp amid the lesser orbs of night, and alternately anticipates the morning dawn and ushers in the evening twilight. When she is to the westward of the sun, in winter, she cheers our mornings with her vivid light, and is a prelude of the near approach of the break of day and the rising sun. When

she is eastward of that luminary, her light bursts upon us after sunset, before any of the other twinkling orbs of heaven make their appearance; and she discharges, in some measure, the functions of the absent moon. The brilliancy of this planet has been noticed in all ages, and has been frequently the subject of description and admiration both by shepherds and by poets. The Greek poets distinguished it by the name of *Phosphor* when it rose before the sun, and *Hesperus* when it appeared in the evening after the sun retired; and it is now generally distinguished by the name of the Morning and Evening Star.

"Next Mercury, Venus runs her larger round,
With softer beams and milder glory crown'd;
Friend to mankind, she glitters from afar,
Now the bright *evening*, now the *morning* star.
From realms remote she darts her pleasing ray,
Now leading on, now closing up the day;
Term'd *Phosphor* when her *morning* beams she yields,
And *Hesp'rus* when her ray the *evening* gilds."

Before proceeding to a more particular description of this planet, I shall lay before the reader a brief explanation of the nature of the planetary orbits, as I may have occasion to refer to certain particulars connected with them in the following descriptions. All the planets and their satellites move in elliptical orbits, more or less eccentric. The following figure exhibits the form of these orbits.

Fig. 9.

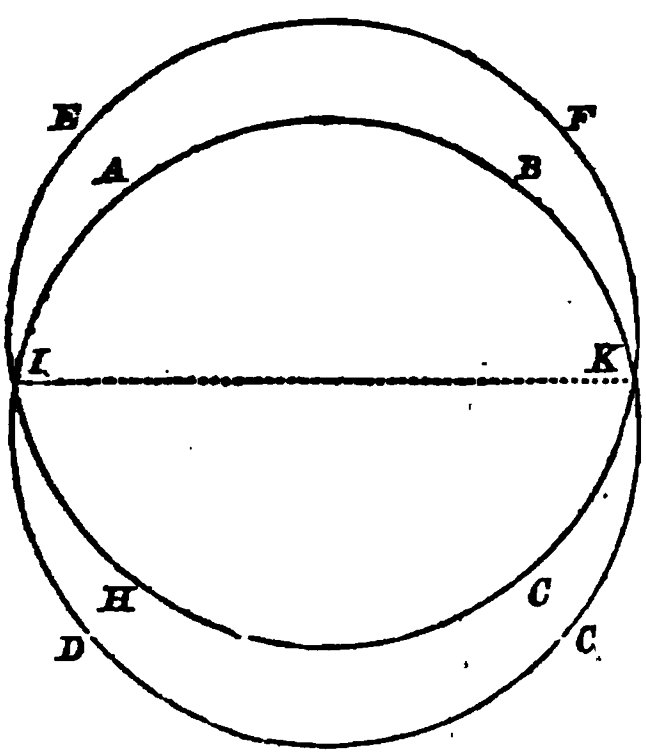



The figure *A D B E* represents the form of a planetary orbit, which is that of an oval or ellipse. The longest diameter is *A B*; the shorter diameter *D E*. The two points *F* and *G* are called the *foci* of the ellipse, around which, as two central points, the ellipse is formed. The sun is not placed in *C*, the centre of the orbit, but at *F*, one of the foci of the ellipse. When the planet, therefore, is at *A*, it is nearest the sun, and is said to be in its *perihelion*; its distance from the sun gradually increases till it reaches the opposite point, *B*, when it is at its greatest distance from the sun, and is said to be in its *aphelion*; when it arrives at the points *D* and *E* of its orbit, it is said to be at the *mean distance*. The line *A B*, which joins the perihelion and aphelion, is called the *line of the apsides*, and also the greater axis or the *transverse* axis of the orbit; *D E* is the *lesser* or *conjugate* axis; *F D*, the *mean distance* of the planet from the sun; *F C*, or *G C*, the *eccentricity* of the orbit, or the distance of the sun from its centre; *F* is the *lower focus*, or that in which the sun is placed; *G* the *higher focus*; *A* the *lower apsis*, and *B* the *higher apsis*. The orbits of some of the planets are more elliptical than others. The eccentricity of the orbit of Mercury is above 7,000,000 miles; that is, the distance from the point *F*, where the sun is placed, to the centre, *C*, measures that number of miles; while the eccentricity of Venus is only about 490,000 miles, or less than half a million. Most of the planetary orbits, except those of some of the new planets, approach very nearly to the circular form.

The orbits of the different planets do not all lie in the same plane, as they appear to do in orreries and in the representations generally given of the solar system. If we suppose a plane to pass through the earth's orbit, and to be extended in every direction, it will trace a line in the starry heavens which is called the *ecliptic*, and the plane itself is called the *plane of the ecliptic*. The orbits of all the other planets do not lie in this plane, one half of each orbit rising above it, while the other half falls below it. This may be illustrated by supposing a large bowl or concave vessel to be nearly filled with water; the surface of the water will trace a circular line round the inner surface of the bowl, which may represent the ecliptic, while the surface of the water itself is the *plane* of the ecliptic, and the bowl is the one half of the concave sky. If we now immerse in the bowl a large circular ring obliquely, so that one half of it is above the surface of the water and the other half below, this ring will represent the orbit of a planet inclined to the ecliptic or to the fluid surface; or if we take two large rings or hoops of nearly equal size, and place the one within the other obliquely, so that the half of the one hoop may be above, and the opposite half below the other hoop, it will convey an idea of the inclination of a planet's orbit to the plane of the ecliptic. Thus, if the circle *E F G H* (Fig. 10) represent the plane of the earth's orbit or the ecliptic, the circle *A B C D* may represent the orbit of a planet which is inclined to it; the semicircle *I A B K* being below the level of the ecliptic, and the other half or semicircle being above it. The points of intersection at *I* and *K*, where the circles cut one another, are called the *nodes*. If the planet is moving in the direction *A I D*, the

point *I*, where it ascends above the plane, is called the *ascending node*, and the opposite

Fig. 10.




point, *K*, the *descending node*. The line *I K*, which joins the nodes, is called the *line of the nodes*, which, in the different planetary orbits, points to different parts of the heavens. It is when Mercury and Venus are at or near the line of the nodes that they appear to make a transit across the sun's disk. The moon's orbit is inclined to the plane of the earth's orbit in an angle of about five degrees; and it is only when the full moon or change happens at or near the *nodes* that an eclipse can take place, because the sun, moon, and earth are then nearly in the same plane; at all other times of full or change, the shadow of the moon falls either above or below the earth, and the shadow of the earth either above or below the moon. The ecliptic is supposed to be divided into twelve signs, or 360 degrees, which have received the following names:—*Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, *Virgo*, *Libra*, *Scorpio*, *Sagittarius*, *Capricornus*, *Aquarius*, *Pisces*. Each of these signs is divided into thirty equal parts, called *degrees*; each degree into sixty parts, or minutes; each minute into sixty parts, or seconds, &c.

Having stated the above definitions, which it may be useful to keep in mind in our further discussions, I shall proceed to a particular description of the motions and other phenomena of Venus.

*General Appearances and apparent Motions of Venus.*—This planet, as already noticed, is only seen for a short time, either after sunset in the evening, or in the morning before sunrise. It has been frequently seen by means of the telescope, and sometimes by the naked eye, at noonday, but it was never seen at midnight, as all the other planets may be, with the exception of Mercury. It never appears to recede further from the sun than forty-seven degrees, or about half the distance from the horizon to the zenith. Of course, it was never seen rising in the east or even shining in the south after the sun had set in the west, as happens in regard to all the other heavenly bodies, with the exception now stated.

When this planet, after emerging from the solar rays, is first seen in the evening, it appears very near the horizon about twenty minutes after sunset, and continues visible only for a very short time, and descends below the horizon not far from the point where the sun went down. Every succeeding day its apparent distance from the sun increases; it rises to a higher elevation, and continues a longer time above the horizon. Thus it appears to move gradually eastward from the sun for four or five months, till it arrives at the point of its greatest elongation, which seldom exceeds forty-seven degrees, when it appears for some time stationary; after which it appears to commence a retrograde motion from east to west, but with a much greater degree of apparent velocity; approaching every day nearer the sun, and continuing a shorter time above the horizon, till, in the course of two or three weeks, it appears lost in the splendour of the solar rays, and is no longer seen in the evening sky till more than nine or ten months have elapsed. About eight or ten days after it has disappeared in the evening, if we look at the eastern sky in the morning, a little before sunrise, we shall see a bright star very near the horizon, which was not previously to be seen in that quarter; this is the planet Venus, which has passed its inferior conjunction with the sun, and has now moved to the westward of him, to make its appearance as the morning star. It now appears every succeeding day to move pretty rapidly from the sun to the westward, till it arrives at the point of its greatest elongation, between 45° and 48° distant from the sun, when it again appears stationary; and then returns eastward, with an apparently slow motion, till it is again immersed in the sun's rays, and arrives at its superior conjunction, which happens after the lapse of about nine months from the time of being first seen in the morning. But the planet is not visible to the naked eye all this time on account of its proximity to the sun when slowly approaching its superior conjunction. After passing this conjunction it soon after appears in the evening, and resumes the same course as above stated. During each of the courses now described, when viewed with a telescope, it is seen to pass successively through all the phases of the moon, appearing *gibbous* or nearly round when it is first seen in the evening; of the form of a half moon when

about the point of its greatest elongation; and of the figure of a crescent, gradually turning more and more slender as it approaches its inferior conjunction with the sun. Such are the general appearances which Venus presents to the attentive eye of a common observer, the reasons of which will appear from the following figure and explanations.

Fig. 11.

Let the earth be supposed at *K*; then when Venus is in the position marked *A*, it is nearly in a line with the sun as seen from the earth, in which position it is said to be in its *superior* conjunction with the sun, or beyond him, in the remotest part of its orbit from the earth; in which case the body of the sun sometimes interposes between the earth and Venus; at other times it is either a little above or below the sun, according as it happens to be either in north or south latitude. When it is in this position the whole of its enlightened hemisphere is turned towards the earth. As it moves on its orbit from *A* to *B*, which is from west to east, and is called its *direct* motion, it begins to appear in the evening after sunset. When it arrives at *B*, it is seen among the stars at *L*, in which position it assumes a gibbous phase, as a portion of its enlightened hemisphere is turned from the earth. When it arrives at *C*, it appears among the stars at *M*, at a still greater distance from the sun, and exhibits a less gibbous phase, approaching to that of a half moon. When arrived at *D*, it is at the point of its greatest eastern elongation, when it appears like a half moon, and is seen among the stars at *N*; it now appears for some time stationary; after which it appears to move with a rapid course in an opposite direction, or from east to west, during which it presents the form of a crescent, till it approaches so near the sun as to be overpowered with the splendour of his rays. When arrived at *E*, it is said to be in its *inferior* conjunction, and, consequently, nearest the earth. In this position it is just 27 millions of miles from the earth; whereas, at its superior conjunction, it is no less than 163 millions of miles from the earth, for it is then further from us by the whole diameter of its orbit, which is 136 millions of miles. This is the reason why it appears much smaller at its superior conjunction than when near its inferior; although, in the latter case, there is only a small crescent of its light presented to us, while in the former case its full enlightened hemisphere is turned to the earth.

The following figure will exhibit more distinctly the *phases* of this planet in the different parts of its course, and the reason of the difference of its apparent magnitude in different points of its orbit. At *A* it is in the superior conjunction, when it presents to our view a round full face. At *B* it appears as an evening star, and exhibits a gibbous phase, somewhat less than a full moon. At *D* it approaches somewhat nearer to a half moon. At *E*, near the point of its eastern elongation,

Fig. 12.

it appears like a half moon. During all this course it moves from west to east. From *F* to *I* it appears to move in a contrary direction, from east to west, during which it assumes the figure of a crescent, gradually diminishing in breadth, but increasing in extent, till it arrives at *I*, the point of its inferior conjunction, when its dark hemisphere is turned towards the earth, and is consequently invisible, being in a situation similar to that of the moon at the time of change. It is seen no longer in the evenings, but soon appears in the morning under the figure of a slender

crescent, and passes through all the other phases represented in the diagram, at *M*, *N*, *O*, &c., till it arrives again at *A*, its superior conjunction. The earth is here supposed to be placed at *K*; and if it were at rest in that position, all the changes now stated would happen in the course of 224 days. But as the earth is moving forward in the same direction as the planet, it requires some considerable time before Venus can overtake the earth, so as to be in the same position as before with respect to the earth and the sun. The time, therefore, that intervenes between the superior conjunction and the same conjunction again is nearly 584 days, during which period Venus passes through all the variety of its motions and phases as a morning and evening star.

This diversity of motions and phases, as formerly stated, serves to prove the truth of the system, now universally received, which places the sun in the centre, and the earth beyond the orbit of Venus. In order to illustrate this point to the astronomical tyro in the most convincing manner, I have frequently used the following plan. With the aid of a planetarium, and by means of an ephemeris or a nautical almanac, I place the earth and Venus in their true positions on the planetarium, and then desire the learner to place his eye in a line with the balls representing Venus and the earth, and to mark the *phase* of Venus, as seen from the earth, whether gibbous, a half moon, or a crescent. I then adjust an equatorial telescope (if the observation be in the daytime), and, pointing it to Venus, show him this planet *with the same phase* in the heavens; an experiment which never fails to please and to produce conviction.

It has generally been asserted by astronomers that it is impossible to see Venus at the time of its superior conjunction with the sun. Mr. Benjamin Martin, in his "Gentleman and Lady's Philosophy," vol. i., says, "At and about her upper conjunction Venus cannot be seen, by reason of her nearness to the sun." And in his "Philosophia Britannica," vol. iii., the same opinion is expressed: "At her superior conjunction Venus would appear a full enlightened hemisphere, *were it not that she is then lost in the sun's blaze*, or hidden behind his body." Dr. Long, in his "Astronomy," vol. i., says, "Venus, in her superior conjunction, *if she could be seen*, would appear round like the full moon." Dr. Brewster, in the article of *Astronomy* in the "Edinburgh Encyclopædia," when describing the phases of Mercury and Venus, says, "Their luminous side is completely turned to the earth at the time of their superior conjunction, when they would appear like the full moon, *if they were not then eclipsed by the rays of the sun*." The same opinion is expressed in similar phrases by Ferguson, Gregory, Adams, Gravesend, and most other writers on the science of astronomy, and has been copied by all subsequent compilers of treatises on this subject. In order to determine this point, along with several others, I commenced, in 1813, a series of observations on the celestial bodies *in the daytime*, by means of an equatorial instrument. On the 5th of June that year, a little before midday, when the sun was shining bright, I saw Venus distinctly with a magnifying power of sixty times, and a few minutes afterward with a power of thirty, and even with a power of fifteen times. At this time the planet was just 3° in longitude and about 13′ in time east of the sun's centre, and, of course, only $2\frac{3}{4}$° from the sun's limb. Cloudy weather prevented observations when Venus was nearer the sun.* On the 16th of October, 1819, an observation was made, in which Venus was seen when only six days and nineteen hours past the time of her superior conjunction. Her distance from the sun's eastern limb was then only 1° 28′ 42″. A subsequent observation proved that she could be seen when only 1° 27′ from the sun's margin, which approximates to the nearest distance from the sun at which Venus is distinctly visible. About the tenth of March, 1826, I had a glimpse of this planet within a few hours of its superior conjunction, but the interposition of clouds prevented any particular or continued observations. It was then about 1° $25\frac{1}{2}$′ from the sun's centre. Observations were likewise made to determine how near its *inferior* conjunction this planet may be seen. The following is the observation in which it was seen nearest to the sun. On March 11th, 1822, at thirty minutes past twelve, noon, the planet being only thirty-five hours past the point of its inferior conjunction, I perceived the crescent of Venus by means of an equatorial telescope, magnifying about seventy times. It appeared extremely slender, but distinct and well-defined, and apparently of a larger curve than that of the lunar crescent when

* The particulars connected with this observation, and with those made on the other planets, and on stars of the first and second magnitudes, together with a description of the instrument, and the manner of making day observations, are recorded in Nicholson's "Journal of Natural Philosophy," &c., for October, 1813, vol. xxxvi. p. 109 to 128, in a communication which occupies about twenty pages; and also, in an abridged form, in the "Monthly Magazine," "Annals of Philosophy," and other periodical journals of that period. During the succeeding winter the celebrated Mr. Playfair, professor of natural philosophy in the university of Edinburgh, communicated, in his lectures to the students, the principal details contained in that communication as *new facts* in astronomical science.

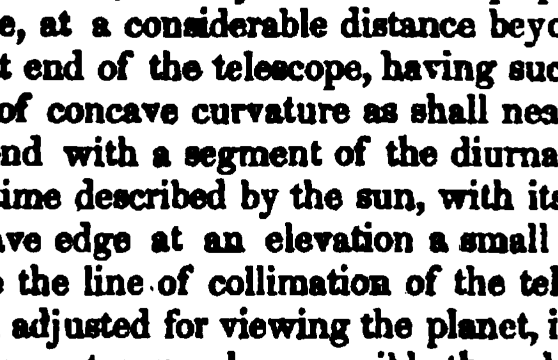
the moon is about two days old. The difference of longitude between the sun and Venus at that time was about 2° 19′. A gentleman who happened to be present perceived the same phenomenon with the utmost ease and with perfect distinctness.*

From the above observations, the following conclusions are deduced: 1. That Venus may be distinctly seen at the moment of her superior conjunction, with a moderate magnifying power, when her geocentric latitude† at the time of conjunction exceeds 1½°, or, at most, 1° 43′. 2. That during the space of 584 days, or about nineteen months, the time Venus takes in moving from one conjunction of the sun to a like conjunction again, when her latitude at the time of her superior conjunction exceeds 1° 43′, she *may be seen by means of an equatorial telescope every clear day without interruption*, except at the moment of her inferior conjunction, and a very short time before and after it, a circumstance which cannot be affirmed of any other celestial body, the sun only excepted. 3. That from the time when Venus ceases to be visible, prior to her inferior conjunction, on account of the smallness of her crescent and her proximity to the sun, to the moment when she may again be perceived in the daytime by an equatorial telescope, there elapses a period of only two days and twenty-two hours; or, in other words, Venus can never be hidden from our view about the time of her inferior conjunction for a longer period than seventy hours. 4. That, during the space of 584 days, the longest period in which Venus can be hidden from our view under any circumstances, excepting a cloudy atmosphere, is about sixteen days and a half. During the same period, this planet sometimes will be hidden from the view of a common observer for the space of five or six months.

One practical use of the above observations is, that they may lead to the determination of the difference (if any) between the polar and equatorial diameters of this planet, which point has never yet been determined. It is well known that the earth is of a spheroidal figure, having its polar shorter than its equatorial diameter. Jupiter, Mars, and Saturn have also been ascertained to be oblate spheroids, and the proportion between their equatorial and polar diameters has been pretty accurately determined. As Venus is found to have a rotation round her axis, as these planets have, it is reasonable to conclude that she is of a similar figure. It is impossible, however, to determine this point when she is in those positions in which she has generally been viewed; as at such times she assumes either a gibbous phase, the form of a half moon, or that of a crescent, in neither of which cases can the two diameters be measured. I am therefore of opinion that, at some future conjunction, when her geocentric latitude is considerable, with a telescope of a high magnifying power, furnished with a micrometer, this point might be ascertained. If the planet is then viewed at a high latitude, and the sky serene, its disk will appear sufficiently luminous and well defined for this purpose; free of that glare and tremulous aspect it generally exhibits when near the horizon, which makes it appear larger than it ought to do, and prevents its margin from being accurately dsitinguished.

Such observations require a considerable degree of attention and care, and various contrivances for occasionally diminishing the aperture of the object glass, and for preventing the direct rays of the sun from entering the tube of the telescope. In order to view this planet to advantage at any future conjunction, when in *south* latitude, it will be proper to fix a board, or any other thin opaque substance, at a considerable distance beyond the object end of the telescope, having such a degree of concave curvature as shall nearly correspond with a segment of the diurnal arc at that time described by the sun, with its lower concave edge at an elevation a small degree above the line of collimation of the telescope, when adjusted for viewing the planet, in order to intercept as much as possible the solar rays. When the planet is in *north* latitude, the curvature of the board must be made *convex*, and placed a little below the line of sight.

Fig. 13.



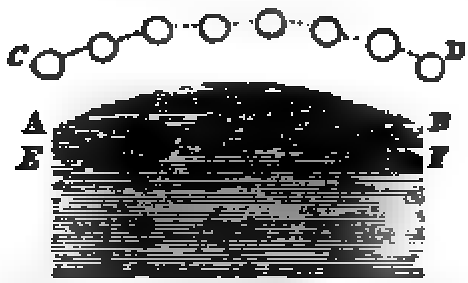

The above figure will illustrate my idea; where *A B* (Fig. 13,) represents the concave curve of the board to be used when the planet

* The observations stated above are also recorded in scientific journals. The observation of the 16th October, 1819, is recorded in the "Edinburgh Philosophical Journal," No. V., for July, 1820, p. 191, 192; and in Dr. Brewster's *second* edition of "Ferguson's Astronomy," vol. ii. p. 111; in the "Monthly Magazine" for August, 1820, vol. i. p. 62. The observation of March 11, 1822, made on Venus when near the *inferior* conjunction, is recorded at large in the "Edinburgh Philosophical Journal," No. XIII., July, 1822, p. 177, 178, &c.

† The *latitude* of a heavenly body is its distance from the ecliptic, or the apparent path of the sun, either north or south. Its *geocentric* latitude is its latitude as seen from the earth. Its *heliocentric* latitude is its latitude as viewed from the sun. These latitudes seldom coincide.

is in south latitude; $C\,D$, a segment of the apparent diurnal path of the planet; and $E\,F$, a segment of the sun's diurnal arc. Fig 14, represents the board to be used when the

Fig. 14.




planet is in *north* latitude, which requires no further description. I have given the above brief statement of the observations on Venus because they are not yet generally known, and because compilers of elementary books on astronomy still reiterate the vague and unfounded assertion that it is impossible to see this planet at its superior conjunction, when it presents a full enlightened hemisphere. The circumstance now ascertained may not be considered as a fact of much importance in astronomy. It is always useful, however, in every department of science, to ascertain every fact connected with its principles, however circumstantial and minute, as it tends to give precision to its language; as it enables the mind to take into view every particular which has the least bearing on any object of investigation; and as it may ultimately promote its progress by leading to conclusions which were not at first apprehended. One of these conclusions or practical uses has been stated above; and another conclusion is, that such observations as now referred to may possibly lead to the discovery of planets yet unknown within the orbit of Mercury, which circumstance I shall take occasion more particularly to explain in the sequel.

*Discoveries made by the telescope in relation to Venus.*—The first circumstance which attracted the attention of astronomers after the invention of the telescope, was, the variety of phases which Venus appeared to assume, of which I have already given a description. Nothing further was observed to distinguish this planet till more than half a century had elapsed, when Cassini, a celebrated French astronomer, in the years 1666–7, discovered some spots on its surface, by which he endeavoured to ascertain the period of its revolution round its axis. October, 14th, 1666, at five hours forty-five minutes, P. M., he saw a bright spot near the limits between the light and the dark side of the planet, not far from its centre; at the same time he noticed two dark oblong spots near the west side of the disk, as represented Fig. 15. After this he could obtain no satisfactory views of Venus till April 20th, 1667, about fifteen minutes before sunrise, when he saw upon the disk, now half enlightened, a bright part, distant from the southern edge about a fourth part of the diameter of the disk, and near the eastern edge. He saw, likewise, a darkish oblong spot towards the northern edge, as in Fig. 16.

Fig. 15. Fig. 16.

At sunrise he perceived that the bright part was advanced farther from the southern point than when he first observed it, as at Fig. 17, when he had the satisfaction of finding an evident proof of the planet's motion. On the next day, at sunrise, the bright spot was a good way off the section, and distant from the southern point a fourth part of the diameter of the disk. When the sun had risen six degrees above the horizon the spot had got beyond the centre. When the sun had risen seven degrees the section cut it in halves, as in Fig. 18, which showed its motion to have some inclination towards the centre.* Seve

Fig. 17. Fig. 18.

ral observations of a similar kind were made about that time, which led Cassini to the conclusion that the planet revolves about its axis in a period somewhat more than twenty three hours. From this time, for nearly sixty years, we have no further accounts of spots having been observed on the disk of Venus.

In the year 1726, *Bianchini*, with telescopes of 90 and 100 Roman palms, commenced a series of observations on Venus, and published an account of them in a book entitled, "*Hes-*

* See "Philosophical Transactions," abridged by Drs. Hutton, Shaw, and Pearson, vol i. part ii. p. 217; "Journal des Savans," vol. i. p. 216; and "*Memoires* of the Royal Academy of Sciences

*veri et Phosphori nova Phenomena.*" In these observations, we do not find that any ne of them was continued long enough to discover any change of position in the spots at the end of the observation from what there was at the beginning; but at the distance of two and of four days he found the same spot advanced so far that he concluded it must have gone round at the rate of 15° in a day. This advance would show that Venus turned round either once in about twenty-four days or in little more than twenty-three hours, but would not determine which of these was the true period. For, if an observer at a given hour, suppose seven in the evening, were to mark the exact place of a spot, and at the same hour on the next day find the spot advanced 15°, he would not be able to determine whether the spot, during that interval of twenty-four hours had advanced forward only 15°, or had finished a revolution, and 15° more as part of another rotation.* Of these two periods Bianchini concluded that the rotation was accomplished in twenty-four days, eight hours. The following is the chief, if not the only observation, he brings forward to substantiate his conclusion. He saw three spots, *A*, *B*, *C*, in the situation represented in Fig. 19, which he and several persons of

Fig. 19.

distinction viewed for about an hour, when they could discover no change of place in their appearance. Venus being hidden behind the Barbarini palace, their view was interrupted for nearly three hours, at the end of which they found that the spots had not sensibly changed their situation. But the inference from this observation is not conclusive for the period of twenty-four days eight hours. For, during the three hours interruption, the spot *C* might have gone off the disk, and the spot *B* moved into its place, where, being near the edge, it would appear less than when in the middle; *A*, succeeding into the place of *B*, would appear larger than it did near the edge, and another spot might have come into the place of *A*. For that there were other spots, particularly one which, by the rotation of Venus, would have been brought into the place of *A*, appears by the figures given by Bianchini; and, if so, it would correspond with the rotation of twenty-three hours twenty minutes deduced by Cassini. Besides, it is impossible to make observations on Venus for three or four hours in succession, as is here supposed, without the help of equatorial instruments, which were not then in use, as this planet is seldom more than three hours above the horizon after sunset; and when it descends within 8° or 10° of the horizon, it is impossible to see its surface with any degree of distinctness, on account of the brilliancy of its light, and the undulating vapours near the horizon, which, in some cases, prevent even its phase from being accurately distinguished. In the communication in "Nicholson's Journal" for 1813, already referred to, I have shown how the dispute in reference to the rotation of Venus may be settled by commencing a series of observations on this planet in the daytime, when its spots, if any were perceived, could be traced in their motion for twelve hours or more. Mr. Ferguson, in his astronomy, by adopting the conclusion of Bianchini, has occupied a number of pages in describing the phenomena on Venus on this supposition, which description is altogether useless, and conveys erroneous ideas of the circumstances connected with this planet, if the period determined by Cassini (as is most probable) be correct.

Mr. Schroeter, formerly mentioned, who has been a most diligent and accurate observer of the heavens, commenced a series of observations in order to determine the daily period of this planet. He observed particularly the different shapes of the two horns of Venus. Their appearance generally varied in a few hours, and became nearly the same at the corresponding time of the subsequent day, or, rather, about half an hour sooner every day. Hence he concluded that the period must be about twenty-three hours and a half; that the equator of the planet is considerably inclined to the ecliptic, and its pole at a considerable distance from the point of the horn. From several observations of this kind he found that the period of rotation must be twenty-three hours, twenty-one minutes, or only one minute more than had been assigned by Cassini; and this, we have reason to believe, is about the true period of this planet's revolution round its axis, being thirty-five minutes less than the period of the earth's rotation, which is twenty-three hours, fifty-six minutes. I have stated these observations respecting the rotation of Venus at some length, because they are not generally known to common readers on this subject, or noticed in modern elementary books on astronomy, and that the general reader may perceive the reason of the

* See some particular remarks on this subject, illustrated with a figure, in my volume "On the Improvement of Society," section iii.

dispute which has arisen among astronomers on this point.

*Mountains on Venus.*—Mr. Schroeter, in his observations, discovered several mountains on this planet, and found that, like those of the moon, they were always highest in the southern hemisphere; their perpendicular heights being nearly as the diameters of their respective planets. From the 11th of December, 1789, to the 11th of January, 1790, the southern horn, *b* (Fig. 20), appeared

Fig. 20. Fig. 21.

much blunted, with an enlightened mountain, *m*, in the dark hemisphere, which he estimated at about 18,300 toises, or nearly twenty-two miles in perpendicular height. It is quite obvious that if such a bright spot as here represented was regularly or periodically seen, it must indicate a very high elevation on the surface of the planet, and its precise height will depend upon its distance from the illuminated portion of the disk, or, in other words, the length of its shadow. It is precisely in such a way that the mountains in the moon are distinguished. Mr. Schroeter measured the altitude of other three mountains, and obtained the following results: height of the first, nineteen miles, or about five times the height of Chimborazo; height of the second, eleven miles and a half; and of the third, ten miles and three quarters. These estimates may, perhaps, require certain corrections in future observations.

*Atmosphere of Venus.*—From several of Mr. Schroeter's observations, he concludes that Venus has an atmosphere of considerable extent. On the tenth of September, 1791, he observed that the southern cusp of Venus disappeared, and was bent like a hook about eight seconds beyond the luminous semicircle into the dark hemisphere. The northern cusp had the same tapering termination, but did not encroach upon the dark part of the disk. A streak, however, of glimmering bluish light proceeded about eight seconds along the dark line, from the point of the cusp, from *b* to *c* (Fig. 21), *b* being the extremity of the diameter of *a b*, and consequently, the natural termination of the cusp. The streak *b c*, verging to a pale gray, was faint when compared with the light of the cusp at *b*. I was struck with a similar appearance when observing Venus, when only thirty-five hours past her inferior conjunction, on March 11, 1822, as formerly noticed, (p. 39). One of the cusps, at least, appeared to project into the dark hemisphere, like a fine lucid thread, beyond the luminous semicircle. This phenomenon Mr. Schroeter considers as the *twilight*, or crepuscular light of Venus. From these and various other observations, which it would be too tedious to detail, he concludes, on the ground of various calculations, that the *dense* part of the atmosphere of Venus is about 16,020 feet, or somewhat above three miles high; that it must rise far above the highest mountains; that it is more opaque than that of the moon; and that its density is a sufficient reason why we do not discover on the surface of Venus those superficial shades and varieties of appearance which are to be seen on the other planets

*Day Observations on Venus.*—The most distinct and satisfactory views I have ever obtained of this planet were taken at noonday, or between the hours of ten in the morning and two in the afternoon, when it happened to be at a high elevation above the horizon, which is generally the case during the summer months. The light of this planet is so brilliant, that its surface and margin seldom appear well defined in the evening, even with the best telescopes. But in the daytime its disk and margin present a sharp and well-defined aspect with a good achromatic telescope, and almost completely free of those undulations which obscure its surface when near the horizon. The following figure (No 1) represents one of the appearances of Venus which I have frequently seen in the daytime when viewing this planet at a high altitude and in a serene sky, when near the meridian, by means of a three-and-a-half feet achromatic telescope, magnifying about 150 times.

Fig. 22.

The exterior curve of the planet, as here

exhibited, appeared far more lucid and bright than the interior portion. It was not a mere stripe or luminous margin, but a broad semicircle, of a breadth nearly one third of the semidiameter of the planet. It appeared as if it were a kind of table-land, or a more elevated portion of the planet's surface, while the interior and darker part appeared more like a plain, diversified with inequalities, and two large spots, somewhat darker than the other parts, were faintly marked. The appearance was somewhat similar to that of certain portions of the level parts of the moon which lie adjacent to a ridge of mountains or a range of elevated ground. I have exhibited this view of Venus at different times to various individuals, and even those not accustomed to look through telescopes could plainly perceive it. I consider it as a corroboration of the fact, that mountains of great elevation exist on the surface of this planet. There appeared likewise some slight indentations in the boundary which separated the dark from the enlightened hemisphere, which circumstance leads to the same conclusions. If the whole hemisphere of the planet had been enlightened, it would propably have appeared as in No. 2. On the whole, I am of opinion that future discoveries in relation to Venus will be chiefly made in the daytime, by large telescopes adapted to equatorial machinery, when such instruments shall be brought into use more than they have hitherto been. Venus, however, is the only planet on which useful observations can be made in the daytime; for although several of the other planets can be perceived, even at noonday, particularly Jupiter, yet they present a very obscure and cloudy appearance compared with Venus, on account of the comparatively small quantity of solar light which falls upon their surfaces.

*Supposed Satellite of Venus.*—Several astronomers have been of opinion that Venus is attended with a satellite, although it is seldom to be seen. It may not be improper to give the reader an abridged view of the observations on which this opinion is founded, that he may be able to judge for himself. The celebrated Cassini, who discovered the rotation of Mars, Jupiter, and Venus, and four of the satellites of Saturn, was the first who broached this opinion. The following is his account of the observations on which it is founded:

"1686, August 18, at fifteen minutes past four in the morning, looking at Venus with a telescope of thirty-four feet, I saw at the distance of three fifths of her diameter, eastward, a luminous appearance, of a shape not well defined, that seemed to have the same phase with Venus, which was then gibbous on the western side. The diameter of this phenomenon was nearly equal to a fourth part of the diameter of Venus. I observed it attentively for a quarter of an hour, and, having left off looking at it for four or five minutes, I saw it no more; but daylight was then advanced. I had seen a like phenomenon, which resembled the phase of Venus, on January 25th, 1672, from fifty-two minutes after six in the morning to two minutes after seven, when the brightness of the twilight caused it to disappear. Venus was then horned, and this phenomenon, the diameter of which was nearly a fourth part of the diameter of Venus was of the same shape. It was distant from the southern horn of Venus, a diameter of Venus on the western side. In these two observations I was in doubt whether it was not a satellite of Venus, of such a consistence as not to be very well fitted to reflect the light of the sun, and which, in magnitude, bore nearly the same proportion to Venus as the moon does to the earth, being at the same distance from the sun and the earth as Venus was, the phases of which it resembled."

In the year 1740, October 23, at sunrise, Mr. Short, with a reflecting telescope of sixteen inches and a half, which magnified about sixty times, perceived a small star at the distance of about ten seconds from Venus; and, putting on a magnifying power of 240 times, he found the star put on the phase of Venus. He tried another magnifying power of 140 times, and even then found the star to have the same phase. Its diameter seemed about a third of the diameter of Venus. Its light was not so bright or vivid, but exceedingly sharp and well defined. A line passing through the centre of Venus and it made an angle with the equator of about twenty degrees. He saw it, for the space of an hour, several times that morning; but, the light of the sun increasing, he lost it about a quarter of an hour after eight. He says he looked for it every clear morning after this, but never saw it again.*

A similar phenomenon is described as having been seen by Baudouin, Montaigne, Rodkier, Montbarron, and other astronomers, and, from their observations, the celebrated M. Lambert, in the "Memoirs of the Academy of Berlin" for 1773, gave a theory of the satellite of Venus, in which he concludes that its period is eleven days, five hours, and thirteen minutes; the inclination of its orbit to the ecliptic, 63¾°; its distance from Venus, 66½ radii of that planet; and its magnitude, 4-27 of that of Venus, or nearly equal to that of our moon. There is a singular consistency in these observations, which it is difficult to account for if Venus have no satellite. Astro-

* "Philosophical Transactions," No. 459, for January, February and March, 1741.

nomers expected that such a body, if it existed, would be seen as a small dark spot upon the sun at the time of the transits of Venus in 1761 and 1769; but no such phenomenon seems to have been noticed at those times by any of the observers. Lambert, however, maintains, from the tables he calculated in relation to this body, that the satellite, if it did exist, might not have passed over the sun's disk at the time of the transits, but he expected that it might be seen alone on the sun when Venus passed near that luminary.

The following is a particular account of the observations made by Mr. Montaigne:—May 3, 1760, he perceived, at twenty minutes distances from Venus, a small crescent, with the horns pointing the same way as those of Venus. Its diameter was a fourth of that of its primary; and a line drawn from Venus to the satellite made, below Venus, an angle with the vertical of about twenty degrees towards the south, as in Fig. 22, No. 3, where *Z N* represents the vertical, and *E C* a parallel to the ecliptic, making then an angle with the vertical of forty-five degrees. The numbers 3, 4, 7, 11 mark the situations of the satellite on the respective days. May 4th, at the same hour, he saw the same star, distant from Venus about one minute more than before, and making an angle with the vertical of ten degrees below, but on the north side; so that the satellite seemed to have described an arc of about thirty degrees, whereof Venus was the centre, and the radius twenty minutes. The two following nights being hazy, Venus could not be seen. But May 7th, at the same hour as on the preceding days, he saw the satellite again, but above Venus, and on the north side, as represented at 7, between twenty-five and twenty-six minutes, upon a line which made an angle of forty-five degrees with the vertical towards the right hand. It appears by the figure that the points 3 and 7 would have been diametrically opposite if the satellite had gone fifteen degrees more round the central point where Venus is represented. May 11th, at nine o'clock P. M., the only night when the view of the planet was not obscured by moonlight, twilight, or clouds, the satellite appeared nearly at the same distance from Venus as before, making with the vertical an angle of forty-five degrees towards the south, and above its primary. The light of the satellite was always very weak; but it had always the same phase with its primary, whether viewed with it in the field of the telescope or alone by itself. He imagined that the reason why the satellite had been so freqently looked for without success might be, that one part of its globe was crusted over with spots, or otherwise unfit to reflect the light of the sun with any degree of brilliancy, as is supposed to be the case with the fifth satellite of Saturn.

Fig. 22.—No. 3.

*North.*

*West.*

*East.*

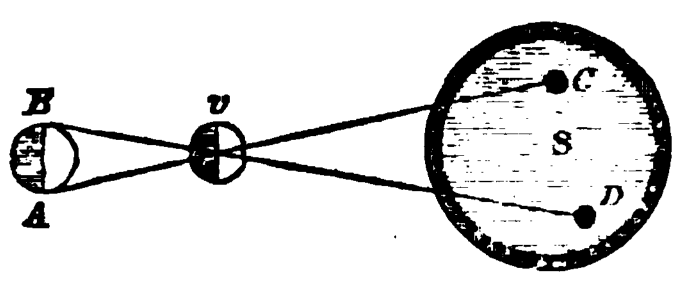
*South.*

It is evident that, if Venus have a satellite, it must be difficult to be seen, and can only be perceived in certain favourable positions. It cannot be seen when nearly the whole of its enlightened hemisphere is turned to the earth, on account of its great distance at such a time, and its proximity to the sun; nor could it be expected to be seen when the planet is near its inferior conjunction, as it would then present to the earth only a very slender crescent, besides being in the immediate neighbourhood of the sun. The best position in which such a body might be detected is near the time of the planet's greatest elongation, and when it would appear about half enlightened. If the plane of its orbit be nearly coincident with the plane of the planet's orbit, it will be frequently hidden by the interposition of the body of Venus, and likewise when passing along her surface in the opposite point of its orbit; and if one side of this body be unfitted for reflecting much light, it will account in part for its being seldom seen. It is not sufficient in this case, to say, as Sir David Brewster has done, "that Mr. Wargentin had in his possession a good achromatic telescope, which always showed Venus with such a satellite, and that the deception was discovered by turning the telescope about its axis." For we cannot suppose that such accurate observers as those mentioned above would have been deceived by such an optical illusion; and, besides, the telescopes which were used in the observations alluded to were both refractors and reflectors, and it is not likely that both kinds of instruments would produce an illusion, especially when three different powers were applied, as in Mr. Short's observations. Were the attention of astronomers more particularly directed to this point than it has hitherto been; were the

number of astronomical observers increased to a much greater degree than at present; and were frequent observations on this planet made in the clear and serene sky of tropical climes, it is not improbable that a decisive opinion might soon be formed on this point; and, if a satellite were detected, it would tend to promote the progress and illustrate the deductions of physical astronomy. It is somewhat probable, reasoning *a priori*, that Venus, a planet nearly as large as the earth, and in its immediate neighbourhood, is accompanied by a secondary attendant.

*Transits of Venus.*—This planet, when in certain positions, is seen to pass like a round black spot across the disk of the sun. These *transits*, as they are called, are of rare occurrence, and take place at intervals of 8 and 113 years. If the plane of the orbit of Venus exactly coincided with that of the earth, a transit would happen at regular intervals of little more than nineteen months; but as one half of this planet's orbit is three degrees and a half below the plane of the earth's orbit, and the other half as much above it, a transit can only take place when it happens to be in one of the *nodes*, or intersections of the orbits, about the time of its inferior conjunction. These transits of Venus are phenomena of very great importance in astronomy, as it is owing to the observations which have been made on them, and the calculations founded on these observations, that the distance of the sun has been very nearly ascertained, and the dimensions of the planetary system determined to a near approximation to the truth. It would be too tedious to enter into a particular explanation of the process and calculations connected with this subject, and therefore I shall only, in a few words, explain the *principle* on which the deductions are founded. Suppose *B A* (Fig. 23) to represent the earth; *v*, Venus; and *S* the sun. Suppose two

Fig. 23.




spectators, *A* and *B*, at opposite extremities of that diameter, of the earth which is perpendicular to the ecliptic; then, at the moment when the observer at *B* sees the centre of the planet projected at *D*, the observer at *A* will see it projected at *C*. If, then, the two observers can mark the precise position of Venus on the sun's disk at any given moment, or note the precise time of ingress or egress of the planet, the angular measure of *C D*, as seen from the earth, might be ascertained. Since *A C* and *B D* are straight lines crossing each other at *v*, they consequently make equal angles on each side of the point *v*; and *C D* will be to *B A* as the distance of Venus from the sun is to her distance from the earth; that is, as 68 to 27, or nearly as 2½ to 1: for Venus is 68 millions of miles from the sun, and 27 millions from the earth, at the time of a transit or an inferior conjunction. *C D*, therefore, occupies a space on the sun's disk 2½ times as great as the earth's apparent diameter at the distance of the sun; or, in other words, it is equal to *five times* the sun's horizontal parallax; and, therefore, any error that might occur in measuring it will amount to only one-fifth of that error on the horizontal parallax that may be deduced from it; and it is on the ground of this parallax that the distance of the sun is determined. The result of all the observations made on the transits which happened in 1761 and 1769 gives about 8¾ seconds as the horizontal parallax of the sun, which makes his distance 95 millions of miles. The distance is considered by the most enlightened astronomers as within *one-fiftieth* part of the true distance of the sun from the earth; so that no future observations will alter this distance so as to increase or diminish it by more than two millions of miles.

The future transits of Venus for the next 400 years are as follows:

| | hours. | minutes. |
|---|---|---|
| 1874, December 9th .... | 4 | 8 A.M. |
| 1882, December 6th .... | 4 | 16 P.M. |
| 2004, June 8th ....... | 8 | 51 A.M. |
| 2012, June 6th ....... | 1 | 17 A.M. |
| 2117, December 11th ... | 2 | 57 A.M. |
| 2125, December 8th .... | 3 | 9 P.M. |
| 2247, June 11th ....... | 0 | 21 P.M. |
| 2255, June 9th ........ | 4 | 44 A.M. |

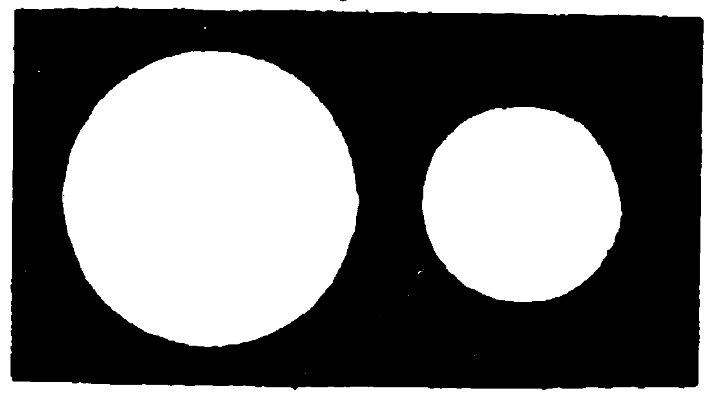
Some of these transits will last nearly seven hours. The next two transits will not be visible throughout their whole duration in Britain or in most countries in Europe. Such was the importance attached to the observations of the last transits in 1761 and 1769, that several of the European states fitted out expeditions to different parts of the world, and sent astronomers with them, to make the requisite observations. This was one end, among others, of the celebrated expedition of Captain Cook, in 1769, to the islands of the Pacific Ocean; and the transit was observed in *Tahiti*, now so celebrated on account of the moral revolution which has lately taken place among its inhabitants.

*Magnitude, and Extent of Surface on this Planet.*—The diameter of Venus has been computed at about 7800 miles; and, consequently, its surface contains 191,134,944, or

above 191 millions of square miles. Taking, as formerly, the population of England as a standard, this planet would contain a number of inhabitants equal to more than 53,500 millions, or nearly sixty-seven times the population of our globe. It does not appear that any great quantity of water exists upon this planet, otherwise there would be a greater contrast between the different parts of its surface, the water presenting a much darker hue than the land. For, if from a high mountain we survey a scene in which a portion of a large river or of the ocean is contained, when the sun is shining on all the objects, we shall find that the water presents a much darker appearance than the land, as it absorbs the greater part of the rays of light, except in a few points between our eyes and the sun, where his rays are reflected from the surface of the fluid; but these partial reflections would be altogether invisible at the distance of the nearest planet. It is pretty evident, however, from what has been formerly stated, that there is a great diversity of surface on this planet; and if some of its mountains be more than twenty miles in elevation, they may present to view objects of sublimity and grandeur, and from their summits extensive and diversified prospects of which we can form no adequate conception. So that Venus, although a small fraction smaller than the earth, may hold a rank in the solar system and in the empire of the almighty, in point of population and sublimity of scenery, far surpassing that of the world in which we dwell.

Having dwelt so long on the phenomena of this planet, I shall state only the following additional particulars: The *quantity of light* on Venus is nearly twice as great as that on the earth, which will, doubtless, have the effect of causing all the colours reflected from the different parts of the scenery of that planet to present a more vivid, rich, and magnificent appearance than with us. Is is probable, too, that a great proportion of the objects on its surface are fitted to reflect the solar rays with peculiar splendour; for its light is so intense as to be distinctly seen by telescopes in the daytime; and, during night, the eye is so overpowered by its brilliancy as to prevent its surface and margin from being distinctly perceived. Were we to indulge our imaginations on this subject, this circumstance might lead us to form various conceptions of the glory and magnificence of the diversified objects which may be presented to the view of the intellectual beings who inhabit this world; but, in the mean time, we have no sufficient *data* to warrant us in indulging in conjectural speculations. The apparent size of the sun as seen from Venus, compared with his magnitude as seen from the earth, is represented in fig. 24, the larger circle showing the size of the sun from Venus.

Fig. 24.



With regard to the *heat* in this planet, according to the principles and facts formerly stated (page 34), it may be modified by the constitution of its atmosphere and the nature of the substances which compose its surface, so that its intensity may not be so great as we might imagine from its nearness to the sun. Even on the supposition that the intensity of the heat of any body is inversely as the square of its distance from the sun, it has been calculated that the greatest heat in Venus exceeds the heat of St. Thomas, on the coast of Guinea, or of Sumatra, about as much as the heat in those places exceeds that of the Orkney Islands or that of the city of Stockholm; and, therefore, at 60 degrees north latitude on that planet, if its axis were perpendicular to the plane of its orbit, the heat would not exceed the greatest heat of the earth, and, of course, vegetation like ours could be carried on, and animals of a terrestrial species might subsist. But we have no need to enter into such calculations in order to prove the habitability of Venus, since the Creator has, doubtless, in this as well as in every other case, adapted the structure of the inhabitant, to the nature of the habitation.

In addition to the above, the following facts may be stated: Venus revolves in an orbit which is 433,800,000 of miles in circumference in the space of 224 days 16 hours; its rate of motion is therefore about eighty thousand miles every hour, one thousand three hundred and thirty miles every minute, and above twenty-two miles every second. Its distance from the sun is 68 millions of miles; and its distance from the earth, when nearest us, is about 27 millions of miles, which is the nearest approach that any of the heavenly bodies (except the moon) make to the earth. Yet this distance, when considered by itself, is very great; for it would require a cannon ball six years and three months to move from the earth to the nearest point of the orbit of Venus, although it were flying every moment at the rate of 500 miles an hour, or 12,000 miles a day. Were the enlightened hemisphere of the planet turned to the earth when it is in this nearest point of its orbit, it would appear like

a brilliant moon, twenty-five times larger than it generally does to the naked eye; but at that time its light side is turned to the sun and away from the earth. At its greatest distance from us it is 163 millions of miles from the earth. The period of its *greatest brightness* is when it is about forty degrees from the sun, either before or after its inferior conjunction, at which time there is only about *one fourth* part of its disk that appears enlightened. In this position it may sometimes be seen with the naked eye even amid the splendours of noonday. In the evening it casts a distinct shadow on a horizontal plane. Sir John Herschel remarks, that this shadow, to be distinguished, "must be thrown upon a white ground. An open window in a whitewashed room is the best exposure; in this situation I have observed not only the shadow, but the diffracted fringes edging its outline." The *density* of Venus compared with that of the sun is as 1 to 383,137, according to La Place's calculations, while that of the earth is as 1 to 329,630; so that the earth is somewhat denser than Venus. A body weighing one pound on the earth will weigh only 15 oz. 10 dr. on the surface of Venus. The *eccentricity* of the orbit of Venus is less than that of any of the other planets; it amounts to 492,000 miles, which is only the 1-276 part of the diameter of its orbit, which, consequently, approaches very nearly to a circle. The inclination of its orbit to the ecliptic is 3° 23′ 33″. Its mean apparent diameter is 17″, and its greatest about 57½″. Its greatest elongation from the sun varies from 45° to 47° 12′. Its mean arc of *retrogradation*, or when it moves from east to west contrary to the order of the signs, is 16° 12′, and its mean duration forty-two days, commencing or ending when it is about 28° 48′ distant from the sun. Such is a condensed view of most of the facts in relation so Venus which may be considered as interesting to the general reader.

### III. OF THE EARTH, CONSIDERED AS A PLANET.

In exhibiting the scenery of the heavens, it is not perhaps absolutely necessary to enter into any particular description of the earth; but as it is the only planetary body with which we are intimately acquainted, and the only standard by which we can form a judgment of the other planetary globes, and as it is connected with them in the same system, it may be expedient to state a few facts in relation to its figure, motion, structure, and general arrangements.

The earth, though apparently a quiescent body in the centre of the heavens, is suspended in empty space, surrounded on all sides by the celestial luminaries and the spaces of the firmament. Though it appears to our view to occupy a space larger than all the heavenly orbs, yet it is, in fact, almost infinitely smaller, and holds a rank only with the smaller bodies of the universe; and, although it appears to the eye of sense immovably fixed in the same position, yet it is, in reality, flying through the ethereal spaces at the rate of more than a thousand miles every minute, as we have already demonstrated. The *figure* of the earth is now ascertained to be that of an oblate *spheroid*, very nearly approaching to the figure of a globe. An orange and a common turnip are oblate spheriods, and are frequently exhibited to illustrate the figure of the earth. But they tend to convey an erroneous idea; for, although a spheroid of ten feet diameter were constructed to exhibit the true figure of the earth, no eye could distinguish the difference between such a spheroid and a perfect globe, since the difference of its two diameters would scarcely exceed one third of an inch; whereas, if its diameters bore the same proportion to each other as the two diameters of an orange generally do, its polar diameter would be nearly one foot three inches shorter than its equatorial.

Before the time of Newton it was never suspected that the figure of the earth differed in any degree from that of a perfect sphere, excepting the small inequalities produced by the mountains and vales. The first circumstance which led to the determination of its true figure was an accidental experiment made with a pendulum near the equator. M. Richer, a Frenchman, in a voyage made to Cayenne, which lies near the equator, found that the pendulum of his clock no longer made its vibrations so frequently as in the latitude of Paris, and that it was absolutely necessary to shorten it in order to make it agree with the times of the stars passing the meridian. Some years after this, Messrs. Deshayes and Varin, who were sent by the French king to make certain astronomical observations near the equator, found that the pendulum at Cayenne made 148 vibrations less in a day than at Paris, and that his clock was retarded by that means two minutes twenty-eight seconds; and was obliged to make his pendulum shorter by two lines, or the sixth part of a Paris inch, in order to make the time agree with that deduced from celestial observations. Similar experiments, attended with the same results, were made at Martinique, St. Domingo, St. Helena, Goree, on the coast of Africa, and various other places, in all which it was found that the alteration was the greatest under the equator, and that it diminished as the observer approached the northern latitudes. This discovery, trifling as it may at first sight appear, opened a new field of investigation to philosophic minds; and there are, perhaps, few facts

throughout the range of science from which so many curious and important facts have been deduced. Sir Isaac Newton and M. Huygens were among the first who perceived the extensive application of this discovery, and the important results to which it might lead. Newton, whose penetrating eye, traced the fact through all its bearings and remote consequences, at once perceived that the earth must have some other figure than what was commonly supposed, and demonstrated that this diminution of weight naturally arises from the earth's rotation round its axis, which, according to the laws of circular motion, repels all heavy bodies from the axis of motion; so that, this motion being swifter at the equator than in other parts more remote, the weight of bodies must also be less there than near the poles. All heavy bodies, when left to themselves, fall towards the earth in lines perpendicular to the horizon; and, were those lines continued, they would all pass through the earth's centre. Every part of the earth, therefore, gravitates towards the centre; and as this force is found to be about 289 times greater than that which arises from the rotation of the earth, a certain balance will constantly be maintained between them, and the earth will assume such a figure as would naturally result from the difference of these two opposite forces. From various considerations and circumstances of this kind, Newton founded his sublime calculations on this subject; and, as Fontenelle remarks, "determined the true figure of the earth without leaving his elbow-chair."

Newton and Huygens were both engaged in these investigations at the same time, unknown to each other, but the results of their calculations were nearly alike. They demonstrated, from the known laws of gravitation, that the true figure of the earth was that of an oblate spheroid, flattened at the poles, and protuberant at the equator; that the proportion between its polar and equatorial diameters is as 229 to 230, and, consequently, that the polar diameter is shorter than the equatorial by about thirty-four miles.* If these deductions be nearly correct, it follows that a degree of latitude in the polar regions must measure more than a degree near the equator. To determine this point by actual measurement, it was ordered by the French king that a degree should be measured both at the equator and within the polar circle. Messrs. Maupertuis, Clairaut, and others were sent to the north of Europe, and Messrs. Bouger, Godin, and La Condamine to Peru, in South America. The first of these companies began their operations at Tornea, near the Gulf of Bothnia, in July, 1736, and finished them in June, 1737. Those who were sent to Peru, having greater difficulties to encounter, did not finish their survey till the year 1741. The results of these measurements were, that a degree of the meridian in Lapland contains 344,627 French feet, and a degree of the meridian at the equator 340,606; so that a degree in Lapland is 4021 French feet, or 4280 English feet, longer than a degree at the equator; that is, they differ about six and a half English furlongs, or 8-10th of a mile. But if the earth had been a perfect sphere, a degree of the meridian in every latitude would have been found precisely of the same length. This spheroidal figure is not peculiar to the earth; for the planets Saturn, Jupiter, and Mars are likewise found to be spheroids, and some of them much flatter at the poles than the earth. The difference between the polar and equatorial diameters of Jupiter is more than 6000 miles.

From the circumstances stated above, we may learn that the most minute facts connected with the system of nature ought to be carefully observed, investigated, and recorded, as they may lead to important conclusions, which, at first view, we may be unable to trace or to appreciate; for in the system of the material world, the greatest and most sublime effects are sometimes produced from apparently simple and even trivial causes. Who could have imagined that such a simple circumstance as the retardation of clocks in southern climes, and the shortening or lengthening of a pendulum, would lead to such an important discovery as the spheroidal figure of the earth? Hence we may conclude, that if ten thousands of rational observers of the facts of nature were to be added to those who now exist, many parts of the scenery of the universe which are now involved in darkness and mystery might ere long be unfolded to our view.

*General Aspect of the Earth's Surface.*—The most prominent and distinguishing feature of the surface of our globe is the two bands of *land* and of *water* into which it is divided. These bands present a somewhat irregular appearance and form, but their greatest length is from north to south. One of these bands of land, generally denominated the *eastern* continent, comprehends Europe, Africa, and Asia, and extends from the Cape of Good Hope on the south to the north-eastern extremity of Kamtschatka, in which direction its length measures about 10,000 miles. Its greatest breadth from Corea, or the eastern parts of Chinese Tartary, to the western extremity of Africa, is about 9000 miles. The

* From a comparison of the length of different degrees of the meridian, lately measured, it is probable that the difference of the diameters is somewhat less than is here stated. Its equatorial diameter is about 7924 miles, and its polar about 7898.

other band of earth is the *western* continent, comprehending North and South America, lying between the Atlantic on the east and the Pacific ocean on the west. Its greatest length is about 8000 miles from north to south, and its greatest breadth, from Nootka Sound to Newfoundland, North America, and from Cape Blanco to St. Roque, South America, is about 3000 miles. Besides these two larger bands of land, there is the large island of New Holland, which is 2600 miles long and 2000 broad, which might be reckoned a third continent; along with many thousands of islands, of every form and size, which are scattered throughout the different seas and oceans. The whole of these solid parts of our globe comprehends an area of about forty-nine millions of square miles, or about one fourth of the superficies of the terraqueous globe, which contains about one hundred and ninety-seven millions of square miles. Were all these portions of the land peopled with inhabitants in the same proportion as in England, the population of the globe would amount to thirteen thousand seven hundred and twenty millions of human beings, which is more than *seventeen* times its present number of inhabitants. Yet, strange to tell, this world has, in all ages, been the scene of wars, bloodshed, and contests for small patches of territory, although the one seventeenth part of it is not yet inhabited!

There is a striking correspondence between two sides of the two continents to which we have adverted, the prominent parts of the one corresponding to the indentings of the other. If we look at a terrestrial globe or map of the world, we shall perceive that the projection of the eastern coast of Africa nearly corresponds with the opening between North and South America, opposite to the Gulf of Mexico; that the projection in South America, about Cape St. Roque and St. Salvador, nearly corresponds with the opening in the Gulf of Guinea; so that, if we could conceive the two continents brought into contact, the openings to which I have referred would be nearly filled up, so as to form one compact continent. The Gulf of Guinea would be nearly blocked up with the eastern projection of South America, and a large gulf formed between Brazil and the land to the eastward of the Cape of Good Hope. The Gulf of Mexico would be formed into a kind of inland lake, and Nova Scotia and Newfoundland would block up a portion of the Bay of Biscay and the English Channel, while Great Britain and Ireland would block up the entrance to Davis's Straits. A consideration of these circumstances renders it not altogether improbable that these continents were originally conjoined, and that, at some former physical revolution or catastrophe, they may have been rent asunder by some tremendous power, when the waters of the ocean rushed in between them, and left them separated as we now behold them. That POWER which is said to "remove mountains," which "shaketh the earth out of her place," and causeth "the pillars thereof to tremble," is adequate to produce such an effect; and effects equally stupendous appear to have been produced when the waters of the great deep covered the tops of the highest mountains, when the solid strata of the earth were bent and disrupted, and rocks of enormous size transported from one region of the earth to another. There appears no great improbability in the supposition that such an event may have taken place at the universal deluge, when the original constitution of the globe seems to have undergone a dreadful change and disarrangement.

Between the two continents now mentioned are two immense bands of water, extending nearly from the northern to the southern extremities of the globe, one of which is 10,000, and the other 3,000 miles broad. These vast collections of water surround the continents and islands, and form numerous seas, straits, gulfs, and bays, which indent and diversify the coasts through every region of the earth. They occupy a square surface of 148,000,000 of miles, forming about three-fourths of the surface of the globe, and containing about 296,000,000 of *cubical* miles of water, sufficient to cover the whole globe to the depth of 2600 yards. This vast superabundance of water, compared with the quantity of land, it is probable, is peculiar to our globe, and that no such arrangement exists on the surface of the other planets of our system. It is probable that such an extensive ocean did not exist at the period of the original formation of the earth, and that such a disproportionate accumulation of water took place in consequence of the deluge. The present constitution of the earth, and the disproportion of the water to the dry land, are circumstances more adapted to a race of fallen intelligences than to beings in a state of innocence, and adorned with the image of their Creator.

Besides the circumstances now stated, the earth is diversified with extensive ranges of mountains, which stretch in different directions along the continents and islands, rearing their summits, in some instances, several miles above the level of the ocean, and diversifying in various modes the landscape of the earth. From these mountains flow hundreds of majestic rivers, some of them more than 2000 miles in length, fertilizing the countries through which they flow, and forming a medium of communication between the inland countries and the ocean. The atmosphere is

thrown around the whole of this terraqueous mass, by means of which, and the operation of the solar heat, a portion of the ocean is carried up to the region of the clouds in the form of vapour, which diffuses itself over every region of the earth, and is again condensed into rains and dews, to supply the sources of the rivers, and to distribute fertility throughout every land. This atmosphere is the region of the *winds*, whether fanning the earth with gentle breezes, or heaving the ocean into mountainous billows, and overturning forests by hurricanes and tornadoes. It is the theatre where thunders roll and lightnings flash, where the fiery meteor sweeps along with its luminous train, and where the *auroræ boreales* display their fantastic coruscations. It is constituted by a law of the Creator to sustain the principle of life, and to preserve in existence and in comfort not only man, but all the tribes of animated existence which traverse the regions of earth, air, or sea, without the benign influence of which this globe would be soon left without a living inhabitant.

Were the earth to be viewed from a point in the heavens, suppose from the moon, it would present a pretty variegated, and sometimes a mottled appearance. The distinction between its seas, oceans, continents, and islands would be clearly marked, which would appear like brighter and darker spots upon its disk. The continents would appear bright, and the ocean of a darker hue, because water absorbs the greater part of the solar light that falls upon it. The level plains (excepting, perhaps, such spots as the Arabian desarts of sands) would appear of a somewhat darker colour than the more elevated and mountainous regions, as we find to be the case on the surface of the moon. The islands would appear like small bright specks on the darker surface of the ocean; and the lakes and Mediterranean seas like darker spots, or broad streaks intersecting the brighter parts or the land. By its revolution round its axis, successive portions of its surface would be brought into view, and present a different aspect from the parts which preceded. Were the first view taken when the middle of the Pacific Ocean appeared in the centre, almost the whole hemisphere of the earth would present a dull and sombre aspect, except a few small spots near the middle, where the Marquesas, the Sandwich, and the Society Isles are situated, and some bright streaks on its north-eastern, north-western, and south-western borders, where the north-western parts of America, the north-eastern parts of Asia and New Holland are situated. In about six hours afterward the whole of Asia, with its large islands, Borneo Sumatra, New Guinea, &c., would come into view and diversify the scene, having a portion of the Pacific on the east, and the Indian Ocean and a portion of Africa on the west. In another six hours the whole of Africa and Europe, the Atlantic Ocean, and the eastern part of South America, would make their appearance; and in six hours more the whole of North and South America would appear near the centre of the view, having the Atlantic Ocean on the east and the Pacific on the west. All these views would present a considerable variety of aspect, but in every one of them the darker shades would appear to cover the greater part of the view, except, perhaps, in that view which takes in the whole of Asia and part of Africa and Europe. Each of these views occasionally present a mottled and unstable appearance, on account of the numerous strata of clouds suspended over different regions, which would be seen frequently to shift their positions. These clouds, when dense, and accumulated over particular countries, would prevent certain portions of the land and water from being distinctly perceived. They would sometimes appear like bright spots upon the ocean, by the reflection of the solar rays from their upper surfaces, and sometimes like dark spots over the land. The following figures represent two of the views to which we have alluded:

Fig. 25. Fig. 26.

Fig. 25, represents the appearance of the earth when the middle of the Pacific is in the centre of the view. Fig. 26, is the appearance when the Atlantic is presented to the spectator's eye, with South and part of North America on the west, and Europe, Africa, and a portion of Asia on the east.

*Internal Structure of the Earth.*—We are now pretty well acquainted with the general outline of the surface of the earth, and the different ramifications of land and water with which it is diversified, except those regions which lie adjacent to the poles. But our knowledge of its *internal* structure is extremely limited. The deepest mines that have ever been excavated do not descend above a mile from the surface; and this depth is no more, compared with the thickness of the earth, than the slight scratch of a pin upon a large artificial globe compared with the ex-

tent of its semidiameter. What species of materials are to be found two or three thousand miles within its surface, or even within fifty miles, will, perhaps, be for ever beyond the power of mortals to determine. Various researches, however, have been lately made as to the materials which compose its upper strata, immediately beneath the surface, and the order in which they are arranged. From these researches we learn that substances of various kinds compose the exterior crust of the globe, and that they are thrown together in almost every possible position; some horizontal, some vertical, and some inclined to each other at various angles. Geologists have arranged the strata of the crust of the earth into various classes: 1. *Primary* rocks, which are supposed to have been formed before all the others, and which compose, as it were, the great frame or groundwork of our globe. These rocks are composed of *granite, gneis, mica-slate*, and other substances; they form the most lofty mountains, and, at the same time, extend themselves downward beneath all the other formations, as if all the materials on the surface of the globe rested upon them as a basis. 2. *Transition* rocks, which are above the primitive, and rest upon them, and are composed of the larger fragments of the primary rocks, consolidated into continuous masses. These rocks contain the remains of certain organized beings, such as sea-shells, while no such remains are found among the rocks termed primitive. 3. *Secondary* rocks, which lie upon the primary and transition rocks, and which appear like deposites from the other species of rocks. The substances which this class of rocks contain are secondary limestone, coal, oolite, sandstone, and chalk. There are likewise *tertiary, basaltic*, and *volcanic* rocks, and *alluvial* and *diluvial* deposites. But it would be foreign to our present subject to descend into particulars.

From facts which have been ascertained respecting these and various other circumstances connected with the constitution of the earth, it has been concluded that important changes and astonishing revolutions have taken place in its physical structure since the period of its formation; that rocks of a huge size have been rolled from one region of the globe to another, and been carried up even to the tops of hills and elevated portions of the land; that the hardest masses of its rocks have been fractured, and its strata bent and dislocated; that in certain places sea-shells, sharks' teeth, the bones of elephants, the hippopotamus, oxen, deer, and other animals, are found mingled together, as if they had been swept along by some overpowering force, amid a general convulsion of nature; that the bed of the ocean has been raised up, by the operation of some tremendous power, so as to form a portion of the habitable surface of the globe; and that the loftiest mountains were once covered by the waters of the ocean. From these and other considerations we have reason to believe that the earth now presents a very different aspect from what it did when it first proceeded from the creating hand of its Maker, and when all things were pronounced by him to be "very good." The earth, therefore, as presently constituted, ought not to be considered as a standard or model to be compared with the other planets of our system, and by which to judge whether they appear to be fitted for being the abodes of intelligent beings. For, in its present state, notwithstanding the numerous objects of sublimity and beauty strewed over its surface, it can be considered as little more than a majestic ruin; a ruin, however, sufficiently accommodated to the character of the majority of inhabitants who have hitherto occupied its surface, whose conduct, in all ages, has been marked with injustice, devastation, and bloodshed.

*Density of the earth.*—In the year 1773, Dr. Maskeline, the astronomer royal, with other gentlemen, made a number of observations on the mountain Schehallien, in Scotland, to determine the *attraction of mountains*. After four months spent in the necessary arrangements and observations, it was ascertained beyond dispute that the mountain exerted a *sensible* attraction, leaving no hesitation as to the conclusion that every mountain and every particle of earth is endowed with the same property in proportion to its quantity of matter. The observations were made on both sides of the mountain, and from these it appears that the sum of the two contrary attractions exerted upon the plumbline of the instruments was equal to eleven seconds and a half. Professor Playfair, more than thirty years afterward, from personal observation, endeavoured to determine the specific gravity or density of the materials of which Schehallien is composed, and, after numerous experiments and calculations, it was concluded that "the mean density of the earth is nearly double the density of the rocks which compose that mountain," which seem to be considerably more dense than the mean of those which form the exterior crust of the earth. The density of these rocks was reckoned to be two and a half times the weight of water; consequently the density of the earth is to that of water as five to one; that is, the whole earth, bulk for bulk, is *five times the weight of water*, so that the earth, as now constituted, would counterpoise five globes of the same size composed of the same specific gravity as water. As the mean density, therefore, of

the whole earth's surface, including the ocean, cannot be above twice the density of water, it follows that the *interior* of the earth must have a much greater density than even five times the weight of water, to counterbalance the want of weight on its surface. Hence we are necessarily led to conclude that the interior parts of the earth, near the centre, must consist of very dense substances, denser than even iron, lead, or silver, and that no great internal cavity can exist within it, as some theorists have supposed, unless we could suppose that most of the materials far below the foundations of the ocean are much denser than the heaviest metallic substances yet discovered. La Place has attempted to estimate the earth's density near the centre on the following data: If 5 2-5 be its mean density, and 3 1-8, 3 1-5, 2 4-5, and 2 3-5 be assumed as its superficial densities, then, on the theory of compressibility, the density at the centre will be 13¼, 14½, 15¼, and 20 1-10 respectively. The least of the specific gravities (13¼) is nearly double the density of zinc, iron, and the ore of lead; and the greatest (20 1-10) is nearly equal to purified and forged *platina*, which is the most ponderous substance hitherto discovered. Yet this ponderous globe, with all the materials on its surface, is carried through the regions of space with a velocity of sixteen hundred thousand miles every day.

*Variety of Seasons.*—The annual revolution of the earth is accomplished in 365 days, 5 hours, 48 minutes, and 51 seconds. In the course of this revolution, the inhabitants of every clime experience, though at different times, a variety of seasons. Spring, summer, autumn, and winter follow each other in constant succession, diversifying the scenery of nature, and distinguishing the different periods of the year. In those countries which lie in the southern hemisphere of the globe, November, December, and January are the summer months, while in the northern hemisphere, where we reside, these are our months of winter, when the weather is coldest and the days are shortest. In the northern and southern hemispheres the seasons are opposite to each other, so that when it is spring in the one it is autumn in the other; when it is winter in southern latitudes it is summer with us. During six months, from March 21 to September 23, the sun shines without intermission on the north pole, so that there is no night there during all that interval, while the south pole is all this time enveloped in darkness. From September to March the south pole enjoys the solar light, while the north, in its turn, is deprived of the sun and left in darkness. The sun is at different distances from the earth at different periods of the year, owing to the earth's moving in an elliptical orbit; but it is not upon this circumstance that the seasons depend. For on the first of January we are more then three millions of miles nearer the sun than on the first of July, when the heat of our summer is generally greatest. The true cause of the variation of the seasons consists in the inclination of the axis of the earth to the plane of its orbit; or, in other words, to the *ecliptic*. If its axis were *perpendicular* to the ecliptic, the equator and the orbit would coincide; and as the sun is always in the plane of the ecliptic, it would in this case be always over the equator; the two poles would be always enlightened, and there would be no diversity of days and nights, and but one season throughout the year. What is meant by the inclination of the axis will appear from the following figures.

Fig. 27. Fig. 28.

Let *A B* represent the plane of the ecliptic, or the earth's orbit, and *C D* (Fig. 28) the axis of the earth, inclined at an angle of 66½° to the ecliptic, and 23½° from the perpendicular *E F*, or the axis of the ecliptic, and it will represent the position of the axis of the earth with respect to the plane of its orbit. Fig. 27 represents the axis of the earth, *G H*, *perpendicular* to the ecliptic. As the sun can enlighten only the one-half of the globe at a time, it is evident that, if his rays come in the direction from *B*, Fig. 28, they cannot illuminate both poles at once. While the north polar circle between *E* and *C* is enlightened, the regions around the south pole between *D* and *F* must necessarily remain in the dark. But if the axis of the earth were perpendicular to its orbit, as exhibited in Fig. 27, then both poles would constantly be enlightened at the same time. The following figure will more particularly show the effect of the inclination of the axis of the earth during its progress through the twelve signs of the zodiac. (See Fig. 29.)

In this representation the ellipse exhibits the earth's orbit seen at a distance, the eye being supposed to be elevated a little above the plane of it. The earth is represented in each of the twelve signs, with the names of the months annexed. In each of the figures *e* is the pole of the ecliptic, and *e d* its axis,

perpendicular to the plane of the orbit. *P* is the north pole of the earth; *P* is its axis, about which the earth daily turns from west to east, *P C e* shows the angle of its inclination.

Fig. 29.

During the whole of its course the axis keeps always in a parallel position, or points always to the same parts of the heavens. If it were otherwise, if the axis of the earth shifted its position in any considerable degree, the most appalling and disastrous effects might be produced; the ocean in many places might overflow the land, and rush from the equator towards the polar regions, and produce a general devastation and destruction to myriads of its inhabitants. If the axis pointed always to the centre of its orbit, so as to be continually varying its direction, all the objects around us would appear to whirl about us in confusion; there would be no fixed polar points to guide the mariner, nor could his course be directed through the ocean by any of the stars of heaven.

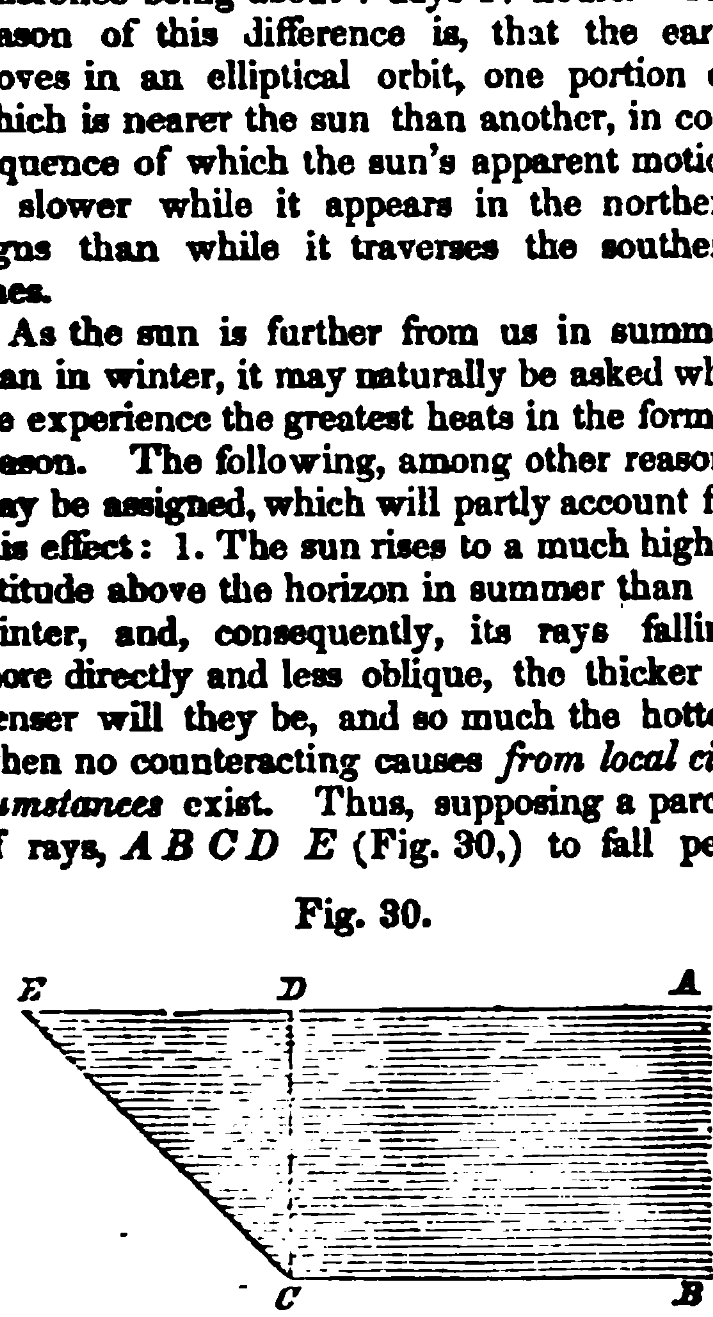
When the earth is in the first point of Libra, the sun appears in the opposite point of the ecliptic, at Aries, about the 21st of March; and when the earth is in Aries, the sun, *S*, will appear in Libra about the 23d of September. At these times both poles of the earth are enlightened, and the day and night are equal in all places. When the earth has moved from Libra to Capricorn, its axis keeping always the same direction, all places within the north polar circle, *P e*, are illuminated throughout the whole diurnal revolution, at which time the inhabitants of those places have the sun more than twenty-four hours above the horizon. This happens at the time of our summer solstice, or about the 21st of June, at which time the south polar circle, *d m*, is in darkness. While the earth is moving from Libra, through Capricorn, to Aries, the north pole, *P*, being in the illuminated hemisphere, will have six months' continual day; but while the earth passes from Aries, through Cancer, to Libra, the north pole will be in darkness, and have continual night; the south pole at the same time enjoying continual day. When the earth is at Cancer, the sun appears at Capricorn, at which season the nights in the northern hemisphere will as much exceed the days as the days exceeded the nights when the earth was in the opposite point of its orbit.

Our summer is nearly eight days longer than our winter. By summer is meant the time that passes between March 21 and September 23, or between the vernal and autumnal equinoxes; and by winter, the time between September 23 and March 21, the autumnal and vernal equinoxes. The portion of the earth's orbit which lies north of the equinoctial contains 184 degrees, while that portion which is south of the equinoctial contains only 176 degrees, being eight degrees

less than the other portion, which is the reason why the sun is nearly eight days longer on the north of the equator than on the south. In our summer the sun's apparent motion is through the six northern signs, Aries, Taurus, Gemini, Cancer, Leo, and Virgo; and in our winter, through the six southern. In the former case, from March 21 to September 23, the sun is about 186 days 11 hours in passing through the northern signs, and only 178 days 18 hours in passing through the southern signs, from September 23 to March 21, the difference being about 7 days 17 hours. The reason of this difference is, that the earth moves in an elliptical orbit, one portion of which is nearer the sun than another, in consequence of which the sun's apparent motion is slower while it appears in the northern signs than while it traverses the southern ones.

As the sun is further from us in summer than in winter, it may naturally be asked why we experience the greatest heats in the former season. The following, among other reasons may be assigned, which will partly account for this effect: 1. The sun rises to a much higher altitude above the horizon in summer than in winter, and, consequently, its rays falling more directly and less oblique, the thicker or denser will they be, and so much the hotter, when no counteracting causes *from local circumstances* exist. Thus, supposing a parcel of rays, *A B C D E* (Fig. 30,) to fall per-

Fig. 30.




pendicularly on any plane (*D C*), and *obliquely* on another plane (*E C*), it is evident they will occupy a smaller space (*D C*) in the former than (*E C*) in the latter; and, consequently, their heat would be much greater in the lesser space *D C* than in the greater space *E C*. If, instead of lines, we suppose *D C* and *E C* to be the diameters of surfaces, then the heat on those surfaces will be inversely as the squares of the diameters. Let *D C* be 20 and *E C* 28; the square of 20 is 400, and the square of 28 is 784, which is nearly double the square of *D C*, and, consequently, there is nearly double the quantity of heat on *D C* compared with that on *E C*, in so far as it depends on the *direct* influence of the solar rays; but other causes may concur either to diminish or increase the heat in certain places, to which I have already alluded when describing the phenomena of Mercury. 2. The greater length of the day contributes to augment the heat in summer; for the earth and the air are heated by the sun in the daytime, more than they are cooled in the night, and on this account the heat will go on increasing in the summer, and for the same reason will decrease in winter, when the nights are longer than the days. Another reason is, that in summer, when the sun rises to a great altitude, his rays pass through a much smaller portion of the atmosphere, and are less refracted and weakened by it than when they fall more obliquely on the earth, and pass through the dense vapours near the horizon.

The cause of the variety of the seasons can be exhibited with more clearness and precision by means of machinery than by verbal descriptions; and, therefore, those whose conceptions are not clear and well defined on this subject should have recourse to orreries and planetariums, which exhibit the celestial motions by wheelwork. There is a small instrument, called a *Tellurian*, which has been long manufactured by Messrs. Jones, Holborn, London, which conveys a pretty clear idea of the motions and phases of the moon, the inclination of the earth's axis to the plane of its orbit, and the changes of the seasons. It may be procured at different prices, from 1*l.* 8*s.* to 4*l.* 14*s.* 6*d.*, according to the size and the quantity of the wheelwork.

The subject of the seasons and the variety of phenomena they exhibit have frequently been the themes both of the philosopher and the poet, who have expatiated on the beauty of the contrivance and the benignant effects they produce; and therefore they conclude that other planets enjoy the same vicissitudes and seasons similar or analogous to ours. But although, *in the present constitution of our globe*, there are many benign agencies which accompany the revolutions of the seasons, and are essential to our happiness in the circumstances in which we now exist, yet it is by no means probable that the seasons, *as they now operate*, formed a part of the original arrangements of our terrestrial system. Man was at first created in a state of innocence, and adorned with the image of his Maker; and the frame of nature, we may confidently suppose, was so arranged as to contribute in every respect both to his sensitive and intellectual enjoyment. But neither the horrors of winter, and its dreary aspect in northern climes, nor the scorching heats and appalling thunderstorms which are experienced in tropical climates, are congenial to the rank and circumstances of beings untainted with sin and endowed with moral perfection. Such physical

evils and inconveniences as the change of seasons occasionally produces appear to be only adapted to man in his present state of moral degradation. In the primeval state of the world it is not unlikely that the axis of the earth had a different direction from what it has at present, and that, instead of scorching heats and piercing colds, and the gloom and desolations of winter, there was a more mild and equable temperature, and something approaching to what the poet calls "a perpetual spring." We are assured, from the records of sacred history, that the original constitution of the earth has undergone a considerable change and derangement: its strata were disrupted, "the fountains of the great deep were broken up," and a flood of waters covered the tops of the loftiest mountains; the effects of which are still visible in almost every region of the globe. At that memorable era, it is highly probable, those changes were introduced which diversify the seasons and produce those alarming phenomena and destructive effects which we now behold; but as man advances in his moral, intellectual, and religious career, and in proportion as his mental and moral energies are made to bear on the renovation of the world, he has it in his power to counteract or meliorate many of the physical evils which now exist. Were the habitable parts of the earth universally cultivated, its marshes drained, and its desolate wastes reduced to order and vegetable beauty by the hand of art, and replenished with an industrious and enlightened population, there can be little doubt that the seasons would be considerably meliorated, and many physical evils prevented with which we are now annoyed. And all this is within the power of man to accomplish, provided he chooses to direct his wealth, and his intellectual and moral energies, into this channel. If these remarks have any foundation in truth, then we ought not to imagine that the earth is a standard by which we are to judge of the state of other planetary worlds, or that they are generally to be viewed as having a diversity of seasons similar to ours.

The following facts, in addition to the preceding, may be noted in relation to the earth: Under the equator, a pendulum, of a certain form and length, makes 86,400 vibrations in a mean solar day; but, when transported to London, the same pendulum makes 86,535 vibrations in the same time. Hence it is concluded that the intensity of the force urging the pendulum downward at the equator is to that at London as 86,400 to 86,535, or as 1 to 1.00315; or, in other words, that a mass of matter at the equator weighing 10,000 pounds, exerts the same pressure on the ground as 10,031½ of the *same pounds* transported to London would exert there. If the gravity of a body at the equator be 1, at the poles it will be 1.00569, or about the 1-194 part heavier; that is, a body weighing 194 pounds at the equator would weigh 195 pounds at the north pole; so that the weight of bodies is increased as we advance from the equator to the poles, owing to the polar parts being nearer the centre of the earth than the equatorial, and the centrifugal force being diminished. It is this variation of the action of gravity in different latitudes that causes the same pendulum to vibrate slower at the equator than in other places, as stated above. For a pendulum to oscillate seconds at the equator, it must be thirty-nine inches in length; and at the poles, thirty-nine and one fifth inches.

The *tropical* year, or the time which the sun (or the earth) takes in moving through the twelve signs of the ecliptic, from one equinox to the same equinox again, is three hundred and sixty-five days, five hours, forty-eight minutes, and fifty-one seconds. This is the proper or natural year; because it always keeps the same seasons to the same months. The *sidereal* year is the space of time the sun takes in passing from any fixed star till it returns to the same star again. It consists of three hundred and sixty-five days, six hours, nine minutes, and eleven and a half seconds, being twenty minutes and twenty and a half seconds longer than the true solar year. This difference is owing to the regression of the equinoctial points, which is fifty seconds of a degree every year; and, to pass over this space, the sun requires twenty minutes and twenty and a half seconds. The earth moves in an elliptical orbit, whose *eccentricity*, or distance of its foci from the centre, is 1,618,000 miles: that is, the ellipse or oval in which it moves is double the eccentricity, or 3,236,000 miles longer in one direction than it is in another, which is the reason that the sun is further from us at one season of the year than at another. This is ascertained from the variation of the apparent diameter of the sun. About the 1st of January, when he is nearest the earth, the apparent diameter is thirty-two minutes, thirty-five seconds; and on the 1st of July, when he is most distant, it is only thirty-two minutes, thirty-one seconds. This proves that the earth has a slower motion in one part of its orbit than in another. In January it moves at the rate of about 69,600 miles an hour, but in July its rate of motion every hour is only about 66,400 miles; a difference of more than 3000 miles an hour.

### IV. OF THE PLANET MARS.

The earth is placed, in the solar system, in a position between the orbits of Venus and

Mars. The two planets, Mercury and Venus, which are placed *within* the orbit of the earth, and whose orbits lie between it and the sun, are termed the *inferior* planets. Those whose orbits lie *beyond* the orbit of the earth, at a greater distance from the sun, as Mars, Jupiter, Saturn, and Uranus, are termed *superior* planets. The motions and aspects of all the superior planets, as seen from the earth, differ considerably from those which are exhibited by the inferior. In the first place, the inferior planets are never seen but in the neighbourhood of the sun, none of them ever appearing beyond forty-eight degrees from that luminary; whereas the superior planets appear at all distances from the sun, even in the opposite quarter of the heavens, or 180 degrees from the point in which the sun may happen to be placed. This could not possibly happen unless their orbits were *exterior* to that of the earth, and the earth placed at such times between them and the sun. In the next place, the inferior planets, when viewed through telescopes, exhibit, at different times, all the phases of the moon; but the superior planets never appear either horned or in the shape of a half moon. The planets Jupiter, Saturn, and Uranus never appear in any other shape than *round*, or with full enlightened hemispheres. This circumstance of itself furnishes a proof that we see these planets always in a direction not very remote from that in which they are illuminated by the solar rays; and, consequently, that we occupy a station which is never very far removed from the centre of their orbits. It proves, in other words, that the path of the earth round the sun is entirely included within their orbits, and likewise that this circular path of the earth *is of small diameter compared with their more expansive orbits*. This may be illustrated by the following figures. Let *S*, Fig. 32, represent the sun; *A B* the orbit of the earth; and *C* the planet Saturn, about ten times further from the sun than the earth is. Suppose *B* to represent the earth at its greatest elongation from the sun, as seen from Saturn; the angle, *S C B*, being so small, it is evident that an observer on the earth, at *B*, can see little or nothing of the dark hemisphere of Saturn at *C*, but must perceive the whole enlightened hemisphere of the planet, within a small fraction, which fraction is not perceptible by our best telescopes.

There is only one of the superior planets that exhibits any perceptible *phase*, and that is the planet *Mars*. In Fig. 31, *S* represents the sun; *E D* the orbit of the earth; *M* Mars; and *D* the earth at its greatest elongation, as seen from Mars. In this case the angle *S M D* is much larger than in the former case, as Mars is much nearer to the earth than Saturn or any other of the superior planets. Consequently, a spectator on

Fig. 31.

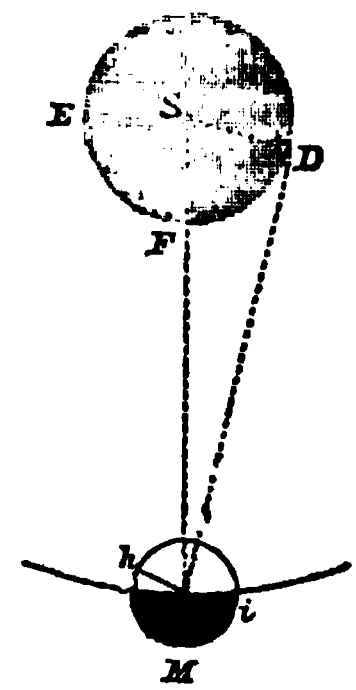



Fig. 32.

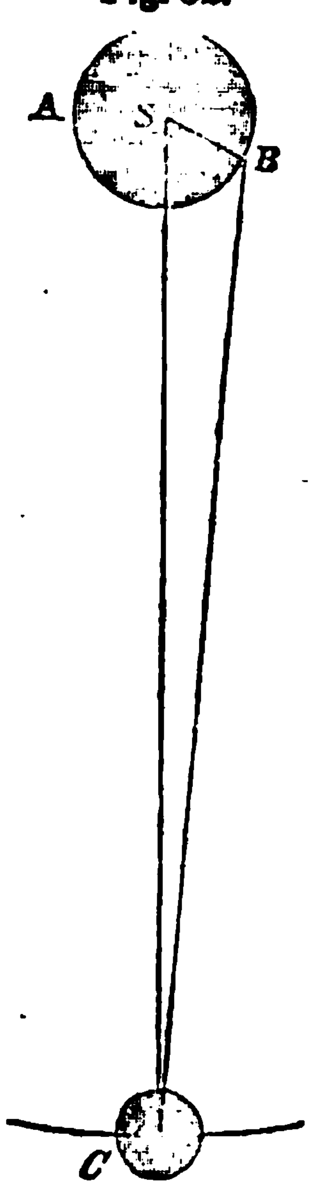
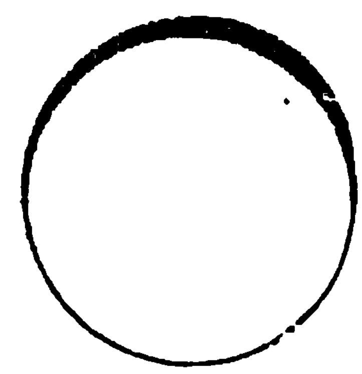



Fig. 33.

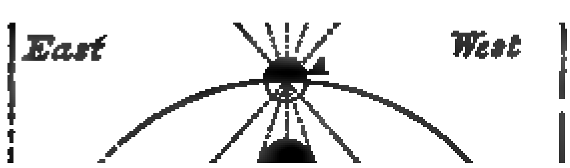


the earth is enabled to see a greater portion of the dark hemisphere of Mars, and, of course, loses sight of a corresponding portion of his enlightened disk. This is represented by the line *h i*. This *gibbous* phase of Mars, however, differs only in a small degree from a circle; it is never less than seven eighths of the whole disk. This phase is represented in Fig. 33. When the earth arrives near the point *F*, when Mars appears in opposition to the sun, the whole of his enlightened hemisphere is then visible. The extent of the gibbous phase of this planet affords a measure of the angle *S M D*, and, therefore, of the proportion of the distance, *S M* of Mars, to *S D* or *S F*, the distance of the earth from the sun, by which we are warranted to conclude that the *diameter of the orbit* of Mars cannot be less than 1 1-2 that of the orbit of the earth. The phases of Saturn, Jupiter, and Uranus being quite imperceptible, demonstrates that their orbits must include both the orbit of the earth and that of Mars; and, consequently, that they are removed at a much greater distance than either of these bodies from the centre of the system.

Before proceeding to a particular description of the phenomena connected with the planet Mars, I shall give a brief sketch of the *motions* peculiar to this planet, which will

serve, in some measure, as a specimen of the apparent motions of all the other superior planets. In the following figure *S* represents the sun; *A B C D* the planet Mars in four different positions in its orbit; *E F G H I K*, the orbit of the earth; and *L M N O P*, a segment of the starry heavens. Suppose Mars at *A* and the earth at *E*, directly between it and the sun, then all the planet's enlightened hemisphere will be turned towards the earth, and it will appear like the full moon. When the planet is at *B* it will be *gibbous*, like the moon a few days before or after the full. At *C* it would again appear wholly enlightened, were it not in the same part of the heavens with the sun.

Fig. 34.




At *D* it is again gibbous, as seen from *E*, and will appear less gibbous as it advances towards *A*. At *A* it is said to be in *opposition* to the sun, being seen from the earth at *E* among the stars at *N*, while the sun is seen in the opposite direction, *E C*. When the planet is at *C* and the earth at *E*, it is said to be in *conjunction* with the sun, being in the same part of the heavens with that luminary. In regard to all the superior planets, there is but *one* conjunction with the sun during the course of their revolution; whereas the inferior planets, Mercury and Venus, have *two* conjunctions, as formerly explained. Let us now attend to the *apparent* motions of this planet. Suppose the earth at *F*, and the planet at rest in its orbit at *A*, it will be projected or seen by a ray of light among the stars at *L*; when the earth arrives at *G*, the planet will appear at *M*, by the ray *G M*; and in the same manner, when the earth is at *H*, *I*, and *K*, the planet will be seen among the stars at *N*, *O*, and *P*; and, therefore, while the earth moves over the large part of its orbit, *F H K*, the planet will have an apparent motion from *L* to *P* among the stars, and this motion is from west to east, in the order of the signs, or in the same direction in which the earth moves; and the planet is then said to be *direct* in motion. When the earth is at *K* and the planet appears at *P*, for a short space of time it appears *stationary*, because the ray of light proceeding from *P* to *K* nearly coincides with the earth's orbit and the direction of its motion. But when the earth moves on from *K* to *E*, the planet will appear to return from *P* to *N*; and while the earth moves from *E* to *F*, the planet will still continue to retrograde from *N* to *L*, where it will again appear stationary as before. From what has been now stated, it is clear that, since the part of the orbit which the earth describes in passing through *F H K* is much greater than the arch *K E F*, and the space *L P* which the planet describes in its direct and retrograde motion is *the same*; therefore, *the direct motion is very slow* from *L* to *P*, in comparison of the *retrograde motion* from *P* to *L*, which is performed in much less time.

In the above description I have supposed the planet at *rest* in its orbit at *A*, in order to render the explanation more easy and simple, and the diagram less complex than it would have been had we traced the planet through different parts of its orbit, together with the motions of the earth. But the appearances are the same, whether we suppose the planet to be at rest or in motion. The only difference is in the *time* when the retrograde or direct motions happen, and in *the places* of the heavens where the planet will be at such times situated. What has now been stated in regard to the apparent motions of Mars will apply to Jupiter, Saturn, and all the superior planets, making allowance for the difference of *time* in which their direct and retrograde motions are performed. All the superior planets are retrograde in their apparent motions when in *opposition*, and for some time before and after; but they differ greatly from each other, both in the extent of their *arc* of retrogradation, in the *duration* of their retrograde movement, and in its *rapidity*, when swiftest. It is more extensive and rapid in the case of Mars than of Jupiter, of Jupiter than of Saturn, and of Saturn than of Uranus. The longer the periodic time or annual revolution of a superior planet, the more frequent are its stations and retrogradations; they are less in quantity, but continue a longer time. The mean arc of retrogradation of Mars, or from *P* to *L*, Fig. 34, is sixteen de-

grees, twelve minutes, and it continues about seventy-three days; while the mean arc of retrogradation of Jupiter is only nine degrees, fifty-four minutes, but its mean duration is about 121 days. The time between one opposition of Saturn and another is 378 days, or one year and thirteen days. The time between two conjunctions or oppositions of Jupiter is 398 days, or one year and thirty-three days. But Mars, after an *opposition*, does not come again into the same situation till after two years and fifty days. It is only at and near the time of the opposition of Mars that we have the best telescopic views of that planet, as it is then nearest the earth; and, consequently, when it has passed its opposition for any considerable time, a period of two years must elapse before we see it again in such a conspicuous situation. Hence it is that this planet is seldom noticed by ordinary observers, except during a period of three or four months every two years. At all other times it dwindles to the apparent size of a small star.

*Distance, Motion, and Orbit of Mars.*—This planet is ascertained to be about 145 millions of miles from the sun. From what we have stated above it is obvious that, in the course of its revolution, it is at very different distances from the earth. When at its greatest distance, as when the earth is at *E*, and the planet at *C*, Fig. 34, it is 240 millions of miles from the earth. This will appear from an inspection of the figure. The distance, *E S*, from the earth to the sun is 95 millions of miles; the distance, *S C*, of Mars from the sun is 145 millions. These distances added together amount to the whole distance from *E* to *C*, or from the earth to Mars when in conjunction with the sun. When nearest the earth, as at A, it is only 50 millions of miles distant from us. For as the whole distance of the planet from the sun, *A S*, is 145 millions, subtract the distance of the earth from the sun, *E S*=95 millions, and the remainder will be the distance of the planet, *E A*=50 millions of miles from the earth. Small as this distance may appear compared with that of some of the other planets, it would require more than 285 years for a steam-carriage, moving without intermission at the rate of twenty miles an hour, to pass over the space which intervenes between the earth and Mars at its nearest distance.

From what has been now stated, it is evident that this planet will present a very different aspect as to size and splendour in different parts of its orbit. When nearest to the earth, it appears with a surface twenty-five times larger than it does at its greatest distance, and seems to vie with Jupiter in apparent magnitude and splendour. But, when verging towards its conjunction with the sun, it is almost imperceptible. And this is one proof, among others, of the truth of the Copernican system. All its motions, stations, and direct and retrograde movements, and the times in which they happen, exactly accord with its position in the system and the motion of the earth, as a planet between the orbits of Venus and Mars. Whereas, were the earth supposed to be the centre of this planet's motion, according to the Ptolemaic hypothesis, it would be impossible to account for any of the phenomena above stated.

The orbit of Mars is 901,064,000, or more than 900 millions of miles in circumference. Through this space it moves in one year and 322 days, or in 16,488 hours. Consequently, its rate of motion is 54,640 miles every hour, which is more than a hundred times the greatest velocity of a cannon ball when it leaves the mouth of the cannon. The diurnal rotation of this planet, or its revolution round its axis, is accomplished in twenty-four hours, thirty-nine minutes, twenty-one seconds, which is about two-thirds of an hour longer than our day. This period of rotation was first ascertained by Cassini, from the motion of certain spots on its surface, which I shall afterward describe. Its axis is inclined to the plane of its orbit in an angle of thirty degrees, eighteen minutes, which is nearly seven degrees more inclined from the perpendicular than that of the earth. This motion is in the same direction as the rotation of the earth, namely, from west to east. The inclination of the orbit of Mars to that of the earth is one degree, fifty-one minutes, six seconds, so that this planet is never so much as two degrees either north or south of the ecliptic. The orbit of Mars is considerably *eccentric*. Its eccentricity is no less than 13,463,000 miles, or about 1-21 of its diameter, which is more than eight times the eccentricity of the orbit of the earth. Hence it follows, that Mars, when in opposition to the sun, may be nearer the earth by a considerable number of millions of miles at one time than at another, when he happens to be about his *perihelion*, or nearest distance from the sun at such opposition. On the 27th of August, 1719, this planet was in such a position, being in opposition within two and a half degrees of its perihelion, and nearer to the earth than it had been for a long period before; so that its magnitude and brightness were so much increased that, by common spectators, it was taken for a new star.

*Appearance of the Surface of Mars when viewed through Telescopes.*—It was not before the telescope was brought to a certain degree of perfection that spots were discovered on the surface of Mars. This instrument was

first directed to the heavens by Galileo, in the year 1610; but it was not till the beginning of 1666 than any of the spots which diversify this planet were discovered. On the 6th of February, that year, in the morning, Cassini, with a telescope of sixteen feet long, saw two dark spots on the face of Mars, as represented in Fig. 35; and on February 24, in the evening, he saw on the other face of the planet two other spots, somewhat like those of the first, but larger, as represented in Fig. 36.

Fig. 35. Fig. 36.

These figures are copied from the first volume of the Transactions of the Royal Society. Afterward, continuing his observations, he found the spots of these two faces to turn by little and little from east to west, and to return at last to the same situation in which he had first seen them. Campani and several other astronomers observed similar spots about the same time at Rome, and Dr. Hook in England. Some of these observers were led to conclude, from the motion of these spots, that the rotation of this planet was accomplished in thirteen hours; but Cassini, who observed them with particular care, proved that the period of rotation was about twenty-four hours and forty minutes, and showed that the error of the other astronomers arose from their not distinguishing the difference of the spots which appeared on the opposite sides of the disk of Mars. The deductions of Cassini on this point have been fully confirmed by subsequent observations.

Maraldi, a celebrated French mathematician and astronomer, made particular observations on these spots in the year 1704. He observed that the spots were not always well defined, and that they often changed their form, not only in the space of time from one opposition to another, but even within the space of a month; but some of them continued of the same form long enough to ascertain their periods. Among these was an oblong spot, not unlike one of the broken belts of Jupiter, that did not reach quite round the body of Mars, but had, not far from the middle of it, a small protuberance towards the north, so well defined as to enable him to settle the period of its revolution at twenty-four hours, thirty-nine minutes; only one minute less than as Cassini had determined it. This appearance of Mars is represented in Fig. 37. On the 27th of August, 1719, the same observer with a telescope of thirty-four feet in length, perceived, among several other spots, a long belt that reached about half way round the planet, not parallel to its equator, to the end of which another short belt was joined, so as to form an angle a little obtuse, as represented in Fig. 38.

Fig. 37. Fig. 38.

The following figures represent the appearance of the spots as seen by Dr. Hook in 1666. He saw Mars on March 3, 1666, as represented in Fig. 39, which appearance was taken down at the moment of observation. On the 23d of the same month he perceived the spots as delineated in Fig. 40, which appears to have been either the same spots in another position, or some other spots on the other hemisphere of the planet.

Fig. 39. Fig. 40.

The following are two views of this planet by Sir William Herschel, who has given a great variety of delineations of the different appearances of Mars in the Transactions of the Royal Society of London for 1784.

Fig 41. Fig. 42.

My own views of this planet have not been numerous, as it is only at intervals of two years, when near its opposition, that observations can be made on its surface with effect

I have, however, distinctly perceived its surface as delineated in Figures 43 and 44.

Fig. 43. Fig. 44.

These observations were made in November and December, 1832, and in January, 1837, and the appearances were very nearly the same; but the spots as represented in the two figures were seen at different times, and were evidently on different hemispheres of the planet, which were presented in succession by its motion of rotation. The instrument used in the observations was a 44½ inch achromatic telescope, with magnifying powers of 150 and 180 times.

Besides the dark spots here delineated, there is a small portion of the globe of Mars, round its south pole, which has, at least occasionally, a much brighter appearance than the other parts. Maraldi, who made observations on Mars about the year 1719, says that this bright spot had been noticed for sixty years before that period, and that it is more permanent than any of the other spots of Mars; that this segment or zone is not all of equal brightness, more than one half of it being brighter than the rest; that the part which is least bright is subject to great changes, and has sometimes disappeared; and that there has sometimes been seen a similar luminous zone round the north pole of Mars, which has appeared of different brightness in different years. The bright spot at the polar point is represented at *a*, Figures 41 and 42. These white spots have been conjectured to be snow, as they disappear when they have been long exposed to the sun, and are greatest when just emerging from the long night of the polar winter in that planet. This is the opinion of Sir W. Herschel, in his paper on this subject in the Philosophical Transactions. "In the year 1781," says this astronomer, "the south polar spot was extremely large, which we might well expect, as that pole had but lately been involved in a whole twelvemonth's darkness and absence of the sun; but in 1783 I found it considerably smaller than before, and it decreased continually from the 20th of May till about the middle of September, when it seemed to be at a stand. During this last period the south pole had already been about eight months enjoying the benefit of summer, and still continued to receive the sunbeams, though, towards the latter end, in such an oblique direction as to be but little benefited by them. On the other hand, in the year 1781, the north polar spot, which had then been its twelvemonth in the sunshine, and was but lately returning into darkness, appeared small, though undoubtedly increasing in size." Hence he concludes, "that the bright polar spots are owing to the vivid reflection of light from frozen regions, and that the reduction of those spots is to be ascribed to their being exposed to the sun."

*Atmosphere of Mars.*—From the gradual diminution of the light of the fixed stars when they approach near the disk of Mars, it has been inferred that this planet is surrounded with an atmosphere of great extent. Although the extent of this atmosphere has been much overrated, yet it is generally admitted by astronomers that an atmosphere of considerable density and elevation exists. Both Cassini and Roemer observed a star, at six minutes from the disk of Mars, become so faint before it was covered by the planet that it could not be seen even with a three feet telescope; which, in all probability, was caused by the light of the star being obscured by passing through the dense part of the atmosphere of the planet. It is doubtless owing to this circumstance that Mars presents so *ruddy* an appearance, more so than any other planet or star in the nocturnal sky. When a beam of light passes through a dense medium, its colour inclines to red, the other rays being partly reflected or absorbed. Thus the morning and evening clouds are generally tinged with red, and the sun, moon, and stars, when near the horizon, either rising or setting, uniformly assume a ruddy aspect, because their light then passes through the lower and denser part of our atmosphere. When the light of the sun passes through the atmosphere of Mars, the most refrangible colours, such as the violet, will be partly absorbed; and before the reflected rays reach the earth, they must again pass through the atmosphere of the planet, and be deprived of another portion of the most refrangible rays; and, consequently, the red rays will predominate, and the planet assume a dull red colour. This I conceive to be the chief reason why I could never perceive Mars in the daytime, even when in the most favourable position, so distinctly as Jupiter, although the quantity of solar light which falls on this planet is more than eleven times greater than what falls on Jupiter; which seems to indicate that Jupiter is surrounded with a less dense and more transparent atmosphere. Sir W. Herschel, though he questions the accuracy of some of the observations of the dimness caused by the appulses of the fixed stars to this planet, yet

admits that it has a considerable atmosphere. "For," says he, "besides the permanent spots on its surface, I have often noticed occasional changes of partial bright belts, and also once a darkish one in a pretty high latitude: and these alterations we can hardly ascribe to any other cause than the variable disposition of clouds and vapours floating in the atmosphere of the planet."

*Conclusions respecting the Physical Constitution of Mars.*—From the preceding observations and the views we have exhibited of this planet, I presume we are warranted to deduce, with a high degree of probability, the following conclusions: 1. That land and water, analogous to those on our globe, exist in the planet Mars. The dark spots are obviously the water or seas upon its surface, which reflect a much less proportion of the solar light than the land. "The seas," says Sir John Herschel, "by a general law in optics, appear *greenish,* and form a contrast to the land. I have noticed this phenomenon on many occasions, but never more distinct than on the occasion when the drawing was made;" from which the figure of Mars in his "Astronomy" is engraved. It is not improbable, from the size of the dark spots compared with the whole disk of Mars, that about one-third or one-fourth of the surface of that planet is covered with water. If this estimate be nearly correct, it will follow that the quantity of land and water on Mars is nearly in a reverse proportion to that which obtains on our globe, where the quantity of water is nearly four times greater than that of the land. The dark spots in some of the views given above seem to convey the idea of several large gulfs or bays running up into the land. The various appearances of these spots which we have delineated are partly owing to the different relations and positions in which they appear during different periods of the planet's rotation, as I have already shown would happen in the appearance of the earth were it viewed from a distance in the heavens (see page 51.) 2. It is probable, too, that there are strata of clouds of considerable extent occasionally floating in the atmosphere of Mars; for some of the observers referred to above have remarked that some of the spots "changed their form in the course of a month;" and Sir W. Herschel, as above stated, declares that he has noticed "occasional changes of partial bright belts, and also once of a darkish one." These, in all probability, were clouds of greater or less density, which, for the most part, would appear brighter than the seas by the reflection of the solar rays from their upper surfaces; for although the *under* surface of dense clouds appears dark to us who view them from below, yet, were we to view their upper surface from a distance when the sun shines upon them, they would undoubtedly present a bright appearance by the reflection of the solar rays. It is doubtless owing to the occasional interposition of such clouds in the atmosphere of Mars that the *permanent* spots sometimes appear to vary their form and aspect. 3. A variety of seasons, somewhat similar to ours, must be experienced in this planet. The diversity of seasons on our globe arises chiefly from the inclination of its axis to the plane of the ecliptic. Now, in reference to Mars, the axis of rotation is inclined to its orbit at even a greater angle than that of the earth; and, therefore, the contrast between its opposite seasons is probably more marked and striking than on the earth. The seasons will also continue for a much longer period than with us, as the year in Mars is nearly double the length of ours, so that summer and winter will be prolonged for a period of eight or nine months respectively. If the opinion of Sir W. Herschel be correct, that the white spots at the poles of Mars are caused by the reflection of the sun's rays from masses of ice and snow, it will afford an additional proof of the existence of a diversity of seasons on this planet, and that its inhabitants are subjected to a winter of great severity and of long duration. 4. This planet bears a more striking resemblance to the earth than any other planet in the solar system. Its distance from the sun, compared with that of the other superior planets, is but a little more than that of the earth. The distinction of land and water on its surface is more strikingly marked than on any of the other planets. It is encompassed with an atmosphere of considerable extent. It is probable that large masses of clouds are occasionally formed in that atmosphere, such as sometimes hover over the whole of Britain, and even of Europe, for several weeks at a time. The length of the day is nearly the same as ours, and it has evidently a succession of different seasons. Were we warranted from such circumstances to form an opinion respecting the physical and moral state of the beings that inhabit it, we might be apt to conclude that they are in a condition not altogether very different from that of the inhabitants of our globe.

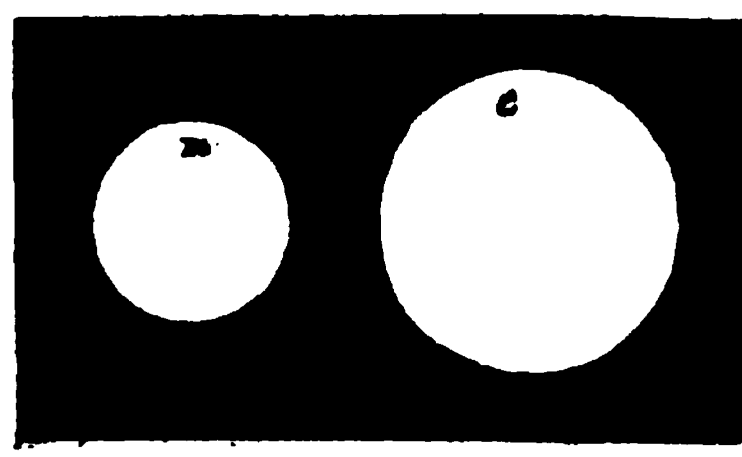
*Magnitude and Extent of Surface of Mars.*—This planet is now estimated to be about 4200 miles in diameter, which is only a little more than half the diameter of the earth. It contains 38,792,000,000, or more than 38 thousand millions of solid miles; and the number of square miles on its surface is 55,417,824, or more than fifty-five millions, which is about six millions of square miles

more than on all the habitable parts of our globe. At the rate of population formerly stated, 280 to a square mile, it would contain a population of more than fifteen thousand five hundred millions, which is nineteen times the number of the inhabitants of the earth; but, as it is probable that one-third of the surface of Mars is covered with water, should we subtract one-third from these sums there would still remain accommodation for twelve times the number of the population of our globe.

No *moon* or secondary planet has yet been discovered about Mars; yet this is no proof that it is destitute of such an attendant; for as all the secondary planets are much less than their primaries, and as Mars ranks among the smallest planets of the system, its satellite, if any exist, must be extremely small. The second satellite of Jupiter is only the 1-43 part of the diameter of that planet; and a satellite bearing the same proportion to Mars would be only ninety-seven miles in diameter. But, suppose it were double this size, it could scarcely be distinguishable by our telescopes, especially when we consider that such a satellite would never appear to recede to any considerable distance from the margin of Mars. The distance of the first satellite of Jupiter is only three diameters of that planet from its centre; and the distance of the first satellite of Saturn is but one diameter and two-thirds from its centre. Now, if a satellite of the size we have supposed were to revolve round Mars at the distance of only two or three of its diameters, its nearness to the body of Mars would generally prevent its being perceived, unless with telescopes of very great power and under certain favourable circumstances; and it could never be expected to be seen but about the time of that planet's opposition to the sun, which happens only at an interval of more than two years. If such a satellite exist, it is highly probable that it will revolve at the nearest possible distance from the planet, in order to afford it the greatest quantity of light; in which case it would never be seen beyond two minutes of a degree from the margin of the planet, and that only in certain favourable positions. If the plane of its orbit lay nearly in a line with our axis of vision, it would frequently be hidden either by the interposition of the body of Mars or by transiting its disk. It is therefore possible, and not at all improbable, that Mars may have a satellite, although it has not yet been discovered. It is no argument for the non-existence of such a body that we have not yet seen it; but it ought to serve as an argument to stimulate us to apply our most powerful instruments to the regions around this planet with more frequency and attention than we have hitherto done, and it is possible our diligence may be rewarded with the discovery. The long duration of winter in the polar regions of Mars seems to require a moon to cheer them during the long absence of the sun; and if there be none, the inhabitants of those regions must be in a far more dreary condition than the Laplanders and Greenlanders of our globe.

*Proportion of Light on the Surface of Mars.*—As the quantity of solar light on any of the planets is in an inverse proportion to their distances from the sun, the quantity of light which falls upon Mars will be much less than that which we enjoy. It is nearly in the proportion of 43 to 100, which is less than one-half of the light which falls upon the earth. This is partly the reason why Mars appears so much less brilliant than Venus, but it is not the only reason; for Jupiter appears much more brilliant than Mars, although he is placed at a much greater distance from the sun. The refraction, reflection, and absorption of the rays of light, in passing through the dense atmosphere to which we have alluded, form, doubtless, one principal reason why Mars appears more sombre in its aspect than Jupiter or Venus. The following figure re-

Fig. 45.




presents the apparent size of the sun as seen from Mars and the earth. The circle *m* represents the size of the sun as seen from Mars, and *e* as seen from the earth. The degree of *heat* on different parts of this planet will depend upon various circumstances; the inclination of its axis, the positions of places in respect to its equator and poles, the nature of its soil, the materials which compose its surface, the quantity of water in different regions, the constitution of its atmosphere, and other circumstances with which we are unacquainted.

The *figure* of Mars is an *oblate spheroid*, like that of the earth, but much flatter at the poles. Its equatorial diameter is to its polar as 1355 to 1272, or nearly as 16 to 15; consequently, if its equatorial diameter be 4200 miles, its polar diameter will be only 3937, which is 263 miles shorter than the equatorial. The *mass* of this planet compared with that of the sun is as 1 to 1,846,082. Its *density*

compared with water is as 3·2-7 to 1, which is considerably less than that of the earth, but greater than the general density of the rocks and other materials which compose the surface of our globe. A body which weighs one pound on the surface of the earth would weigh only five ounces six drachms on the surface of Mars.

### V. ON THE LATELY-DISCOVERED PLANETS VESTA, JUNO, CERES, AND PALLAS.

The immense interval which lies between the orbits of Mars and Jupiter led some astronomers to surmise that a planet of considerable magnitude might possibly exist somewhere within this limit. This conjecture was grounded on the intervals which exist between the rest of the planetary orbits. Between the orbits of Mercury and Venus there is an interval of 31,000,000 of miles; between those of Venus and the earth, 27,000,000; between those of the earth and Mars, 50,000,000; but between the orbits of Mars and Jupiter there intervenes the immense space of 349,000,000 of miles. Here the order of the solar system was supposed to be interrupted, which would form an exception to the general law of the proportion of the planetary distances. No planetary body, however, was detected within this interval till the beginning of the present century; and, instead of one large body, as was surmised, four very small ones have been discovered. These bodies are situated at a distance from Mars nearly corresponding to the order and proportion to which we have now alluded; and this circumstance leads to a belief "that it is something beyond a mere accidental coincidence, and belongs to the essential structure of the system." As these bodies are invisible to the naked eye, and can only be seen in certain favourable positions, and as only a short period has elapsed since their discovery, we are not yet much aquainted with many of their phenomena and physical peculiarities.

Of these four bodies, the first discovered was that which is now named *Ceres*, and sometimes *Piazzi*, from the name of its discoverer. It was discovered at Palermo, in the island of Sicily, on the 1st of January, 1801, or the first day of the present century, by Piazzi, a celebrated astronomer belonging to that city, who has since distinguished himself by his numerous observations on the fixed stars. This new celestial body was then situated in the constellation Taurus, and, consequently, at no very great distance from its opposition to the sun. It was observed by Piazza till the 12th of February following, when a dangerous illness compelled him to discontinue his observations; but it was again discovered by Dr. Olbers, of Bremen, after a series of unwearied observations and laborious calculations, founded on a few insulated facts which had been stated by Piazza. Dr. Brewster states, in the "Edinburgh Encylopædia," vol. ii. p. 638, and likewise in his second edition of "Ferguson's Astronomy," vol. ii. p. 38, "that the rediscovery of this planet by Olbers did not take place till the 1st of January 1807;" which must be a mistake, for in "*La Decade Philosophiques*," for July, 1803, it is stated that Dr. Olbers, some time before, received La Lande's prize for having discovered the planet Pallas; and, at the same time, his merit is referred to in having rediscovered Ceres, and having been among the first that announced it to the world. Besides, Sir W. Herschel has observations on this planet in the "Philosophical Transactions," of date February 7, 1802, which, of course, was posterior to Dr. Olber's rediscovery.

The planet *Pallas*, or, as it is sometimes named, *Olbers*, was discovered on the 28th of March, 1802,—only fifteen months after the discovery of Ceres,—by Dr. Olbers, a physician at Bremen, in Lower Saxony, distinguished for his numerous celestial observations, and for his easy and commodious method of calculating the orbits of comets. The planet *Juno* was discovered on the evening of September 1, 1804, within two years and a half of the discovery of Pallas, by M. Harding, at the observatory of Lilienthal, near Bremen, while endeavouring to form an atlas of all the stars near the orbits of Ceres and Pallas, with the view of making further discoveries. While thus engaged, he perceived a small star of about the eighth magnitude, which was not marked in the Celestial Atlas of La Lande, which he put down in his chart. Two days afterward he found that the star had disappeared from the position in which he had marked it; but a little to the south-west of that position he perceived another star resembling it in size and colour; and having observed it again on the 5th of September, and finding that it had moved a little in the same direction as before, he concluded that it was a moving body connected with the solar system.

The planet *Vesta* was discovered on the 29th of March, 1807, little more than two years and a half after the discovery of Juno, so that four primary planets belonging to our system, which had been hidden for thousands of years from the inhabitants of our globe, were discovered within the space of little more than six years. Vesta must then have been near its opposition. The discovery of Vesta was made by Dr. Olbers, who had previously discovered Pallas, and rediscovered Ceres. He had formed an idea that the three small bodies lately discovered might possibly be the

fragments of a larger planet, which had been burst asunder by some unknown and powerful irruptive force proceeding from its interior parts, and that more fragments might still be detected. Whether this opinion be tenable or not, it seems to have led to the discovery of Vesta; for the doctor concluded, if his opinion were just, that although the orbits of all these fragments might be differently inclined to the ecliptic, yet, *as they must all have diverged from the same point*, "they ought to have two common points of reunion, or *two nodes in opposite regions of the heavens*, through which all the planetary fragments must sooner or later pass." One of these nodes, or points of intersection of the orbits, he found to be in the sign *Virgo*, and the other in the constellation of the *Whale*; and it was actually in the regions of the Whale that the planet Juno was discovered by M. Harding. With the view, therefore, of detecting other fragments, if any should exist, Dr. Olbers examined, three times every year, all the small stars in the opposite constellations of Virgo and the Whale, and in the constellation *Virgo* the planet Vesta was first seen.*

* William Olbers, M. D., the discoverer of Vesta and Pallas, was born on the 11th of October, 1758, at Arbergen, a village in the Duchy of Bremen, where his father was a clergyman. His father, besides being a man of great general learning, was a good mathematician and a lover of astronomy. Young Olbers, when in his fourteenth year, felt a great taste for that science. During an evening walk in the month of August, having observed the Pleiades, or seven stars, he became very desirous of knowing to what constellation they belonged. He therefore purchased some charts and books, and began to study this science with the greatest diligence; he read with the greatest avidity every astronomical work he was able to procure, and in a few months made himself aquainted with all the constellations. Finding that a knowledge of mathematics was necessary to the study of astronomy, he devoted all his leisure time to this subject. He was at the same time engaged in the study of medicine as a profession. In the year 1779, when scarcely twenty-one years of age, he observed at Gottingen, and calculated the first comet. An account of this labour was published in the "Berlin Astronomical Calender" for 1782, where it is mentioned that Olbers made his construction one night while attending a patient; and yet it was afterward found that his determination of this orbit corresponded with the most accurate elements of the comet which were calculated. Since that period, the astronomy of comets has been his favourite study, and it is admitted that none of the methods formerly tried for calculating the orbit of a comet is so simple, and, at the same time, so elegant as that of Dr. Olbers. When at Vienna, amid all his applications to the study of Medicine, he was the first who observed the planet Uranus (after its discovery by Herschel) on the 17th of August, 1781. On the 19th he perceived its motion, and continued his observations till the end of September, at which period it was considered as a comet. Returning from the scene of his studies, he settled at Bremen as a physician, where he soon acquired the confidence of his fellow-citizens, both on account of his successful practice and integrity and affability of his character.

This was doubtless a remarkable coincidence of theory with observation, and affords a presumption that the conjecture of this eminent astronomer may possibly have a foundation in fact.

The following is a summary of what has been ascertained respecting the distances, magnitudes, and motions of these bodies:

*The Planet Vesta.*—The mean distance of this planet from the sun is reckoned to be about 225 millions of miles; its annual revolution is completed in about 3 years 7 1-2 months, or in 1325 days; the circumference of its orbit is 1414 millions of miles, and, of course, it moves with a velocity, on an average, of more than 44,000 miles an hour. The inclination of its orbit to the plane of the ecliptic is seven degrees, eight minutes; and its eccentricity 21 millions of miles. The diameter of this planet has been estimated by some astronomers at only about 270 miles; and, if this estimate be correct, it will contain only 229,000 square miles, or a surface somewhat less than Great Britain, France, and Ireland; and, according to the rate of population formerly stated, would contain 64 millions of inhabitants, or about five times the number of the inhabitants of the United States of America, or nearly the twelfth part of the population of the earth. It is probable, however, that this estimate is too small, and that the apparent diameter of this planet has not yet been accurately taken; for the light of this body is considered equal to that of a star of the fifth or sixth magnitude, and it may sometimes be distinguished in a clear evening by the naked eye. Its light is more intense and white than that of either Ceres, Juno, or Pallas; and it is not surrounded with any nebulosity, as some of these planets are. It is not likely that a body of this size could be seen at the distance of 130 millions of miles, which is its nearest approach to the earth, and that, too, by the naked eye (as Schroeter affirms he did several times,) unless the substances on its surface were of such a nature as to reflect the solar rays with a far greater degree of brilliancy than any of the other planets. The diameter of the third satellite of Jupiter is reckoned at 3377 miles, and its surface, of course, contains 35,827,211 square miles, which is 156 times greater than the *surface* of Vesta, according to the above estimation. Yet this satellite can never (or, at least, but rarely) be seen by the naked eye. Vesta is, indeed, only about one third the distance from us of the satellite of Jupiter; but, making allowance for this circumstance, it should be at least twenty times larger *in surface* than is estimated above in order to be seen by the naked eye, or with the same distinctness as the third satellite of Jupiter. In other words, it should have a diame-

ter of at least 1200 miles. If this is not the case, there must be something very peculiar and extraordinary in the reflective power of the materials which compose its surface to produce such an intensity of light from so small a body at so great a distance as 130 millions of miles. I am therefore of opinion that the size of this planet has not yet been accurately ascertained, and that future and more accurate observations are still requisite to determine its apparent diameter and real magnitude.

*The Planet Juno.*—The next planet in the order of the system is Juno. Its distance from the sun is estimated at 254 millions of miles. The circumference of its orbit is 1596 millions of miles. Through this circuit it moves in four years and 128 days, at the rate of 41,850 miles every hour. Its diameter, according to the estimate of Schroeter, is 1425 English miles. Its surface will therefore contain six millions, three hundred and eighty thousand square miles, and a population of one thousand, seven hundred and eighty-six millions, which is more than double the number of the earth's inhabitants. The orbit of Juno is inclined to the ecliptic in an angle of thirteen degrees, three minutes. Its eccentricity is 63,588,000 miles, so that its greatest distance from the sun is 316,968,000 miles, while its least distance is only 189,792,000. Its apparent diameter as seen from the earth is little more than three seconds. This planet is of a reddish colour, and is free from any nebulosity; yet the observations of Schroeter render it probable that it has an atmosphere more dense than that of any of the old planets of the system. A remarkable variation in the brilliancy of this planet has been observed by this astronomer, which he attributes to changes that are going on in its atmosphere, and thinks it not improbable that these changes may arise from a diurnal rotation performed in twenty-seven hours.

*The Planet Ceres.*—This planet is about 263 millions of miles from the sun, and completes its annual revolution in four years, seven months, and ten days. The circumference of its orbit is 1653 millions of miles, and it moves at the rate of about forty-one thousand miles an hour. The eccentricity of its orbit is 20,598,000 miles. Its greatest distance from the sun is 283,500,000 miles, and its least distance 242,300,000. Its apparent mean diameter, including its atmosphere, according to Schroeter, is somewhat more than six seconds at its mean distance from the earth. Its real diameter, according to the estimate of the same astronomer, is 1624 English miles; but, including its atmosphere, is 2974 miles. Its surface, therefore, contains 8,285,580 square miles, or about the one sixth part of the habitable portions of our globe; and would afford accommodation for 2,319,962,400, or more than 2300 millions of inhabitants, according to the rate of population in England, which is nearly triple the present population of the earth. This planet is of a slight ruddy colour, and appears about the size of a star of the eighth magnitude, and is consequently invisible to the naked eye. It seems to be surrounded with a dense atmosphere, and exhibits a disk or sensible breadth of surface when viewed with a magnifying power of two hundred times. Schroeter has determined, from a great number of observations, that its atmosphere is about six hundred and seventy-five English miles in height, and that it is subject to numerous changes. Like the atmosphere of the earth, it is very dense near the planet, and becomes rarer at a greater distance, which causes its apparent diameter to appear somewhat variable. When this planet is approaching the earth, towards the point of its opposition to the sun, its diameter increases more rapidly than it ought to do from the diminution of its distance, which Schroeter supposes to arise from the finer exterior strata of its atmosphere becoming visible while it approaches the earth. He also perceived that the visible hemisphere of the planet was sometimes overshadowed, and at other times cleared up, so that he concludes there is little chance of discovering the period of its diurnal rotation. The inclination of its orbit to the ecliptic is in an angle of ten degrees, thirty-seven minutes. The intensity of light upon its surface is more than seven times less than what we enjoy.

Sir William Herschel, in the year 1802, after the discovery of Ceres and Pallas, made a number of observations to ascertain if any of these bodies were accompanied with satellites. Several very small stars were occasionally perceived near Ceres with high magnifying powers, of the positions and motions of which he has given several delineations; but it did not appear probable, in subsequent observations, that they accompanied the planet. In his observation of April 28, with a power of 550, he says, "Ceres is surrounded with a strong haziness. The breadth of the coma, beyond the disk, may amount to the extent of a diameter of the disk, which is not very sharply defined. Were the whole coma and star taken together, they would be at least three times as large as my measure of the star. The coma is very dense near the nucleus; but loses itself pretty abruptly on the outside, though a gradual diminution is still very perceptible." These observations seem to corroborate the idea that Ceres is encompassed with an atmosphere of great density and elevation.

*The Planet Pallas.*—This planet revolves

about the sun at the mean distance of two hundred and sixty-three millions of miles, and finishes its revolution in 1681 days, 17 hours, or in four years and seven and one third months, which is within a day of the time of the revolution of Ceres. Its distance is likewise nearly the same as that planet, and the circumference of its orbit will also be nearly the same. This planet, however, is distinguished in a remarkable degree both from Ceres and from all the other planets by the very great inclination of its orbit to the plane of the ecliptic. This inclination is no less than thirty-four degrees, thirty-seven minutes, or nearly five times the inclination of Mercury's orbit, which was formerly reckoned to have the greatest inclination of any of the planetary orbits. The *eccentricity* of the orbit of Pallas is likewise greater than that of any of the other planets, being no less than 64,516,000 miles, so that this planet is 129,000,000 of miles nearer the sun in one part of its orbit than it is at the opposite extremity. Its greatest distance from the sun is 327,437,000 miles, and its least distance only 198,404,000 miles. Of course, its rate of motion in its orbit must be very variable, sometimes moving several thousands of miles an hour swifter at one time than at another, which is likewise the case, in a remarkable degree, with the planet Juno. Its *mean motion* is about 41,000 miles an hour.

This planet presents a ruddy aspect, but less so than that of Ceres. It is likewise surrounded with a nebulosity somewhat like that of Ceres, but of less extent. The following are some of the observations of this planet by Schroeter and Herschel. The atmosphere of Pallas, according to Schroeter, is to that of Ceres as one hundred and one to one hundred and forty-six, or nearly as two to three. It undergoes similar changes, but the light of the planet exhibits greater variations. On the 1st of April the atmosphere of Pallas suddenly cleared up, and the solid nucleus or disk of the planet was alone visible. About twenty-four hours afterward the planet appeared pale and surrounded with fog, and this appearance continued during the 3d and 4th of April; but this phenomenon was not considered as arising from the diurnal rotation of the planet. The following are Herschel's observations: "April 22. In viewing Pallas, I cannot, with the utmost attention and under favourable circumstances, perceive any sharp termination which might denote a disk; it is rather what I would call a nucleus. April 22. The appearance of Pallas is cometary; the disk, if it has any, being ill-defined. When I see it to the best advantage, it appears like a much-compressed, extremely small, but ill-defined planetary nebula. May 1. With a twenty feet reflector, power 477, I see Pallas well, and perceive a very small disk, with a coma of some extent about it, the whole diameter of which may amount to six or seven times that of the disk alone."—*Philosophical Transactions* for 1802.

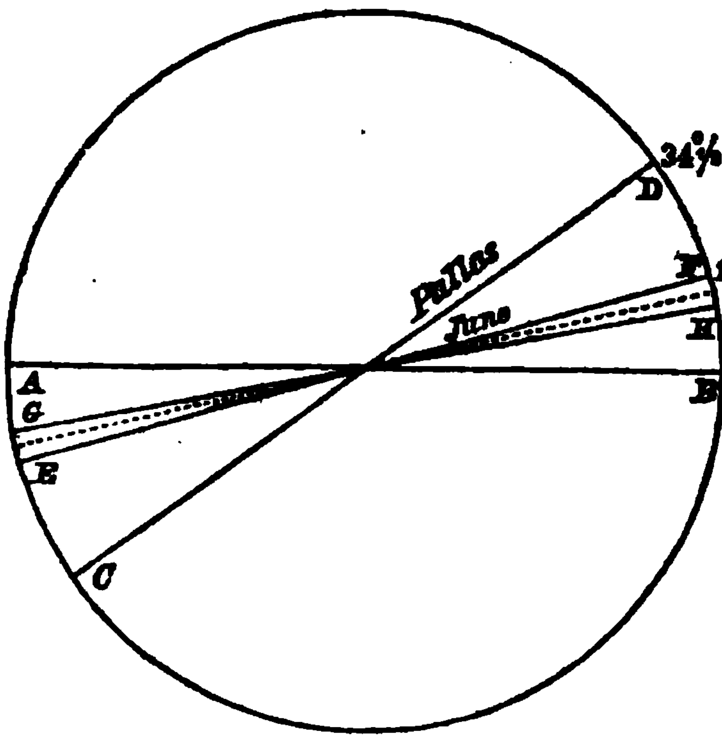
The diameter of this planet has not, perhaps, been ascertained with sufficient precision. The difference in the estimates formed by Sir W. Herschel and M. Schroeter is very great. According to Schroeter, the diameter of Pallas is 2099 miles. If this estimate be nearly correct, Pallas will be about the size of our moon, and will comprehend on its surface nearly fourteen millions of square miles, which would accommodate a population of nearly four thousand millions, or five times the population of our world. The apparent mean diameter of this planet, comprehending its atmosphere, at its mean distance from the earth, according to Schroeter, is six and a half seconds.

Such is a brief view of the principal facts which have been ascertained respecting the planets Vesta, Juno, Ceres, and Pallas. All these bodies are situated between the orbits of Mars and Jupiter, and they are all invisible to the naked eye, except, perhaps, the planet Vesta, when in certain favourable positions. The real magnitudes of these planets are not to be considered as yet accurately determined; they may be a little greater or less than what is stated above, though it is not probable they are much larger. It may not be improper to remark, that on this point there is a great difference in the estimates of Schroeter and Herschel, the two principal observers who have investigated the phenomena of these planets, owing to the mode in which they measured the apparent diameters of these bodies. According to Sir W. Herschel, there is none of these bodies that exceeds 163 miles in diameter. But it is obvious, from the considerations I have stated in the description of Vesta, that bodies of such a small size could not be visible at such a distance, unless they were either luminous or composed of matter fitted to reflect the solar light with an extraordinary degree of brilliancy; and therefore it is far more probable that the estimates of Schroeter are nearest the truth.

*Peculiarities of the New Planets.*—These bodies present to our view various singularities and anomalies, which, at first sight, appear incompatible with the proportion and harmony which we might suppose originally to have characterized the arrangements of the solar system. In the first place, *their orbits have a much greater degree of inclination to the ecliptic than those of the old planets.* The orbit of Venus is inclined to the ecliptic in an angle of three degrees, twenty minutes;

of Mars, one degree, fifty-one minutes; of Jupiter, one degree, eighteen minutes; of Saturn, two degrees and a half; and of Uranus, only forty-six minutes. But the inclination of the orbit of Vesta is seven degrees, nine minutes; of Juno, thirteen degrees; of Ceres, ten degrees, thirty-seven minutes; and of Pallas, no less than thirty-four degrees and a half, which is nineteen times greater than the inclination of Mars, and twenty-seven times greater than that of Jupiter. The proportion of these inclinations is represented in the following figure.

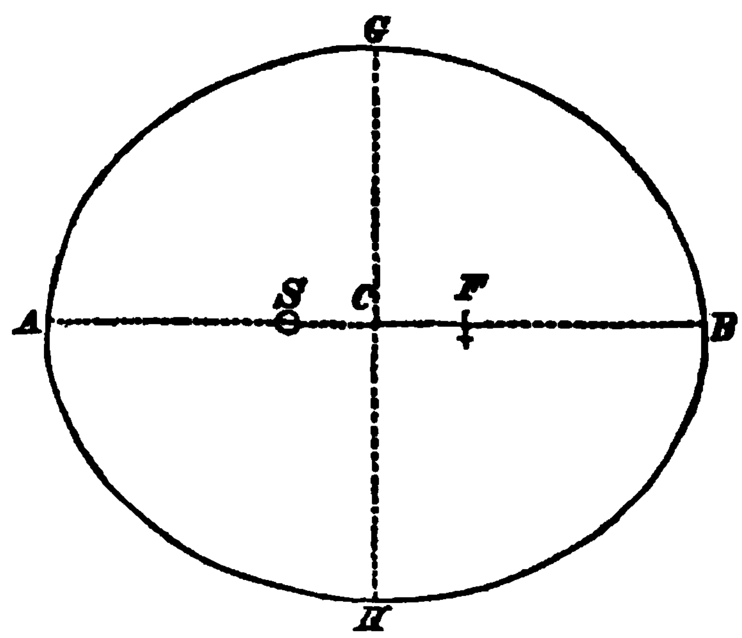
Fig. 46.




Let $A$ $B$ represent the plane of the ecliptic, and the line $C$ $D$ will represent the inclination of the orbit of Pallas = 34½ degrees, $E$ $F$, the inclination of the orbit of Juno = 13 degrees; $G$ $H$, the inclination of Vesta's = 7 degrees; and the dotted line the inclination of Ceres = 10½ degrees. All the older planets have their orbits much less inclined to the ecliptic, except Mercury, which has nearly the same inclination as Vesta; so that the zodiac would now require to be extended nearly five times its former breadth in order to include the orbits of all the planets.

2. *The orbits of these planets are in general more eccentric than those of the other planets;* that is, they move in longer and narrower ellipses. The following figure nearly represents the orbit of Pallas, and the orbit of Juno is nearly similar. $S$ represents the sun in one of the foci of the ellipse; $C$ the centre; $F$ the upper focus of the ellipse; and the whole line $A$ $B$ the transverse diameter. Now the distance $S$ $C$, from the sun to the centre, is the *eccentricity* of the orbit. This eccentricity, in the case of Pallas, amounts to more than sixty-four and a half millions of miles. Consequently, when the planet is at $B$, which is called its *Aphelion*, or greatest distance from the sun, it is double its eccentricity, or the whole length of the line $S$ $F$ further from the sun than when it is at the point $A$, which is called its *Perihelion*, or least distance from the sun, that is, it is 129 millions of miles further from the sun in the one case than in the other, which is nearly *one fourth* of the whole transverse diameter of the orbit $A$ $B$. Consequently, its motion will be much slower by several hundreds of thousands of miles a day when near the point $B$, its aphelion, than when near its perihelion at the point $A$; and to a spectator on its surface the sun will appear more than double the size from the point $A$ that he does from the point

Fig. 47.

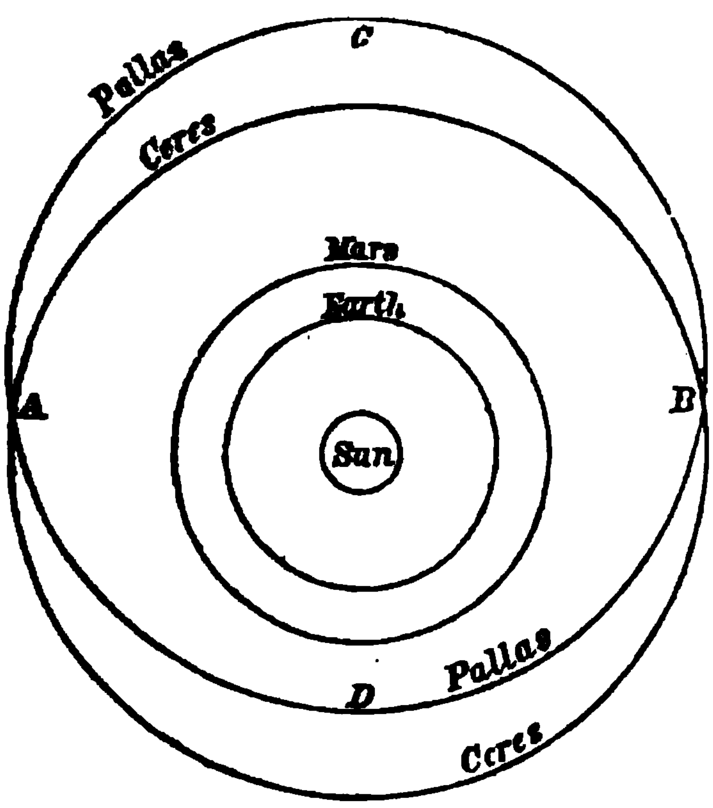



$B$; and its inhabitants (if any) will experience a greater difference in the intensity of the solar light which falls upon them in different periods of its year, than there is between Venus and the earth, or between the earth and Mars. On the other hand, the eccentricity of the orbits of the older planets is comparatively small. The eccentricity of the orbit of Venus is less than half a million of miles, which is only the 1-274 part of the transverse diameter of its orbit. The Earth's eccentricity is 1,618,000 miles, or the 1-119 part; Jupiter's, 1-43 part; Saturn's, 1-38 part; and that of Uranus, about 1-43 part; whereas the eccentricities of Pallas and Juno amount to nearly *one eighth* part of the transverse axes of their orbits. Were the orbits of the old planets represented by figures ten times larger than the above diagram, they could not be distinguished from circles. In the above figure, the dotted line $G$ $H$ is the *conjugate* or shorter diameter of the ellipse. When the planet is at the points $G$ and $H$, it is said to be at its *mean distance* from the sun, or at the middle point between its greatest and its least distance.

3. *The orbits of several of the new planets cross each other.*—This is a very singular and unaccountable circumstance in regard to the planetary orbits. It had been long observed that comets, in traversiug the heavens in every

direction, crossed the orbits of the planets; but, before the discovery of Pallas, no such anomaly was found throughout the system of the planets. For the orbits of all the other planets approach so nearly to circles, and are separated from each other by so many millions of miles, that there is no possibility of such intersection taking place. The following diagram represents the intersection of the orbits of Ceres and Pallas.

Fig. 48.




The central circle represents the sun; the two next circles the orbits of the earth and Mars; and the two outer circles, crossing each other, those of Ceres and Pallas. In consequence of this intersection of their orbits, there is a *possibility*, especially if the periods of their revolutions were somewhat more different from each other, that the two planets might happen to strike against each other were they to meet at the points *A* and *B*, where the orbits intersect, a very singular contingence in the planetary system. It is owing to the very great eccentricity of the orbit of Pallas that it crosses the orbit of Ceres. It is several millions of miles nearer the sun in its perihelion (or at *A*, Fig. 47,) than Ceres, when in the same point of its orbit. But when Pallas is in its aphelion (or at *B*, Fig. 47, ) its distance from the sun is several millions of miles greater than that of Ceres in the same point of its orbit. Suppose its aphelion at *C*, Fig. 48; it is further from the sun than Ceres, and nearer at *D* its perihelion. The same things happen in the case of the other two planets, particularly Vesta. Juno is further from the sun at its aphelion than Ceres in the same point of its orbit, and Vesta is further from the sun in its aphelion than either Juno, Ceres, or Pallas in their perihelions. The perihelion distance of Vesta is greater than that of Juno or Pallas. Hence it follows that Vesta may sometimes be at a greater distance from the sun, than either Juno, Ceres, or Pallas, although its mean distance is less than that of either of them by twenty-eight millions of miles; so that *the orbit of Vesta crosses the orbits of all the other three*, and therefore it is a possible circumstance that a collision might take place between Vesta and any of these three planets, were they ever to meet at the intersection of their orbits. Were such an event to happen, it is easy to foresee the catastrophe that would take place. If the collision of two large ships, sailing at the rate of ten miles an hour, be so dreadful as to shatter their whole frame and sink them in the deep, what a tremendous shock would be encountered by the impulse of a ponderous globe, moving at the rate of forty thousand miles an hour? A universal disruption of their parts and a derangement of their whole constitution would immediately ensue; their axes of rotation would be changed; their courses in their orbits altered; fragments of their substance tossed about through the surrounding void, and the heavens above would appear to run into confusion. Though we cannot affirm that such an event is impossible or will never happen, yet we are sure it can never take place without the permission and appointment of Him who at first set these bodies in motion, and who superintends both the greatest and the most minute movements of the universe.

4. Another peculiarity in respect to these planets is, that *they revolve nearly at the same mean distances from the sun.* The mean distance of Juno is 254 millions of miles; that of Ceres, 262,903,000; and that of Pallas, 262,901,000, which is almost the same as Ceres. This is a very different arrangement from that of the other planets, whose mean distances are immensely different from each other; Mars being 50 millions of miles from the orbit of the earth, and 80 millions from the orbits of any of the new planets; Jupiter, 270 millions from Pallas; Saturn, 412 millions from Jupiter; and Uranus, 900 millions from Saturn. Except in the case of the new planets, the planetary system appears constructed on the most ample and magnificent scale, corresponding to the unlimited range of infinite space of which it forms a part.

5. These new planetary bodies *perform their revolutions in nearly the same periods.* The period of Vesta is three years, 7½ months; that of Juno, 4 years, 4¼ months; of Ceres, 4 years, 7½ months; and of Pallas, 4 years, 7½ months. So that there are only three months of difference between the periods of Juno and Ceres, and scarcely the difference of a single day between those of Ceres and Pallas;

whereas the periods of the other planets differ as greatly as their distances. The period of Mercury is about 3 months; of Venus, 7½ months; of Mars, nearly 2 years; of Jupiter, 12 years; of Saturn, 29½; and of Uranus, nearly 84 years. A planet moving round the sun in almost the same period and at the same distance as another, is a singular anomaly in the solar system, and could scarcely have been surmised by former astronomers.

6. Another singularity is, that these bodies *are all much smaller than the other planets.* Mercury was long considered as the smallest primary planet in the system, but it is nearly four times larger in surface than Ceres, and contains eight times the number of solid miles. Mars, the next smallest planet, is seventeen times larger than Ceres; and Jupiter, the largest of the planets, is 170,000 times larger than Ceres, when their cubical contents are compared. The planets Vesta and Juno are smaller than Ceres, and Pallas is only a small degree larger. It is probable that all these four bodies are less in size than the secondary planets, or the satellites of Jupiter, Saturn, and Uranus.

*Conclusions respecting the Nature of the New Planets.*—The anomalies and peculiarities of these bodies, so very different from the order and arrangement of the older planets, open a wide field for reflection and speculation. Having been accustomed to survey the planetary system as a scene of proportion, harmony, and order, we can scarcely admit that these bodies move in the same paths, and are arranged in the same order as when the system was originally constructed by its Omnipotent Contriver. As we know that changes have taken place in our sublunary region since our globe first came from the hands of its creator, so it is not contrary either to reason or observation to suppose that changes and revolutions, even on an ample scale, may take place among the celestial orbs. We have no reason to believe in the "incorruptibility" of the heavenly orbs, as the ancients imagined, for the planets are demonstrated to be *opaque* globes as well as the earth; they are diversified with mountains and vales, and, in all probability, the materials which compose their surfaces and interior are not very different from the substances which constitute the component parts of the earth. I have already alluded to the opinion of Dr. Olbers, that the new planets are only the fragments of a larger planet which had been burst asunder by some immense irruptive force proceeding from its interior parts. However strange this opinion may at first sight appear, it ought not to be considered as either very improbable or extravagant. We all profess to admit, on the authority of Revelation, that the earth was arranged in perfect order and beauty at its first creation; and on the same authority we believe that its exterior crust was disrupted that "the cataracts of heaven were opened, and the fountains of the great deep broken up," and that a flood of waters ensued which covered the tops of the loftiest mountains, which transformed the earth into one boundless ocean, and buried the immense myriads of its population in a watery grave. This was a catastrophe as tremendous and astonishing as the bursting asunder of a large planet. Although physical agents may have been employed in either case to produce the effect, yet we must admit, in consistency with the Divine perfections, that no such events could take place without the direction and control of the Almighty, and that, when they do happen, whatever appalling or disastrous effects they may produce, they are in perfect consistency with the moral laws by which his universal government is directed.

We know that a moral revolution has taken place among the human race since man was created, and that this revolution is connected with most of the physical changes that have happened in the constitution of our globe; and, if we believe the sacred historian, we must admit that the most prominent of these physical changes or concussions was the consequence or punishment of man's alienation from God and violation of his laws. As the principles of the Divine government must be essentially the same throughout every part of the boundless empire of the Almighty, what should hinder us from concluding that a moral cause, similar to that which led to the physical convulsions of our globe, may have operated in the regions to which we allude, to induce the Governor of the universe to undermine the constitution, and to dash in pieces the fabric of that world? The difference is not great between bursting a planet into a number of fragments and cleaving the solid crust of the earth asunder, removing rocks and mountains out of their place, and raising the bed of the ocean from the lowest abyss, so as to form a portion of elevated land; all which changes appear to have been effected in the by-past revolutions of our globe, and both events are equally within the power and the control of Him "who rules in the armies of heaven and among the inhabitants of the earth," whatever physical agents he may choose to select for the accomplishment of his purposes. In the course of the astronomical discoveries of the two preceding centuries, views of the universe have been laid open which have tended to enlarge our conceptions of the attributes of the Deity, and of the magnificence of that universe over which he presides: and who knows but that the discovery of those

new planets described above, and the singular circumstances in which they are found, are intended to open to our view a new scene of the physical operations of the Creator, and a new display of the operations of his moral government? For all the manifestations of God in his works are doubtless intended to produce on the mind not only an intellectual, but also a *moral* effect; and in this view the heavens ought to be contemplated with as much reverence as the revelations of his word. As the great Sovereign of the universe is described by the inspired writers as being the "King Eternal and *Invisible*," so we can trace his perfections and the character of his moral government only, or chiefly, through the medium of those displays he gives of himself in his wonderful operations both in heaven and on earth. And since in the course of his providence, he has crowned with success the inventive genius of man, and led him on to make the most noble discoveries in reference to the amplitude and grandeur of his works, we have every reason to conclude that such inventions and such discoveries, both in the minute parts of creation and in the boundless sphere of the heavens, are intended to carry forward the human mind to more expansive views of his infinite attributes, of the magnificence of his empire, and of the *moral economy* of the government which he has established throughout the universe.

The hypothesis of the bursting of a large planet between Mars and Jupiter accounts in a great measure, if not entirely, for the anomalies and apparent irregularities which have been observed in the system of the new planets; and if this supposition be not admitted, we cannot account, on any principle yet discovered, for the singular phenomena which these planets exhibit. Sir David Brewster, who has entered into some particular discussions on this subject, after stating the remarkable coincidences between this hypothesis and actual observation, concludes in the following words: "These singular resemblances in the motions of the greater fragments and in those of the lesser fragments, and the striking coincidence between theory and observation in the eccentricity of their orbits, in their inclination to the ecliptic, in the position of their nodes, and in the places of their aphelia, are phenomena which could not possibly result from chance, and which concur to prove, with an evidence amounting almost to demonstration, that the four new planets have diverged from one common node, and have therefore composed a single planet."

Another species of phenomena, on which a great mystery still hangs, might be partly elucidated were the above hypothesis admitted, and that is the singular but not well-attested fact of large masses of solid matter falling from the higher regions of the atmosphere, or what are termed *meteoric stones*. Few things have puzzled philosophers more than to account for large fragments of compact rocks proceeding from regions beyond the clouds, and falling to the earth with great velocity. These stones sometimes fall during a cloudy, and sometimes during a clear and serene atmosphere; they are sometimes accompanied with explosions, and sometimes not. The following statements, selected from respectable authorities, will convey some idea of the phenomena peculiar to these bodies. The first description I shall select is given by J. L. Lyons, Esq., F.R.S., and contained in the "Transactions of the Royal Society." It is entitled, "Account of the Explosion of a Meteor, near Benares, in the East Indies, and of the falling of some Stones at the same time." The following are only the leading particulars. "A circumstance of so extraordinary a nature as the fall of stones from the heavens could not fail to excite the wonder and to attract the attention of every inquisitive mind. On the 19th of December, 1798, about eight o'clock in the evening, a very luminous meteor was observed in the heavens by the inhabitants of Benares and the part adjacent, in the form of a large ball of fire; it was accompanied by a loud noise resembling thunder, and a number of stones fell from it about fourteen miles from the city of Benares. It was observed by several Europeans, as well as natives, in different parts of the country. It was likewise very distinctly observed by several European gentlemen and ladies, who described it as a large ball of fire, accompanied with a loud rumbling noise not unlike an ill-discharged platoon of musketry. It was also seen and the noise heard by several persons at Benares. When a messenger was sent next day to the village near which they had fallen, he was told that the natives had either broken the stones to pieces, or given them to the native collector or others. Being directed to the spot where they fell, he found four, most of which the fall had buried six inches deep in the earth. He learned from the inhabitants that, about eight o'clock in the evening, when retired to their habitations, they observed a very bright light, proceeding as from the sky, accompanied with a loud clap of thunder, which was immediately followed by the noise of heavy bodies falling in the vicinity. They did not venture out to make any inquiries till next morning, when the first circumstance that attracted their attention was the appearance of the earth being turned up in several parts of their fields, where, on examination, they found the stones. Several other stones of the same description were afterward found

by different persons. One of these stones, of about two pounds' weight, fell through the top of the watchman's hut, close to which he was standing, and buried itself several inches in the floor, which was of consolidated earth. The form of the more perfect stones appeared to be that of an irregular cube, rounded off at the edges, but the angles were to be observed on most of them. At the time when the meteor appeared the sky was perfectly serene; not the smallest vestige of a cloud had been seen since the 11th of the month, nor were any observed for many days after. It is well known there are no volcanoes on the continent of India, and therefore they could not derive their origin from any such source; and no stones have been met with in the earth, in that part of the world, which bear the smallest resemblance to those now described."

On the 13th of December, 1795, a stone weighing fifty-six pounds fell near Wold cottage, in Yorkshire, at three o'clock, P. M. It penetrated through twelve inches of soil and six inches of solid chalk rock, and, in burying itself, had thrown up an immense quantity of earth to a great distance; as it fell, a number of explosions were heard as loud as pistols. In the adjacent villages the sound was heard as of great guns at sea; but at two adjoining villages the sounds were so distinct of something passing through the air to the residence of Mr. Topham, that five or six people came up to see if any thing extraordinary had happened at his house. When the stone was extracted, it was warm, smoked, and smelt very strong of sulphur. The day was mild and hazy, but there was no thunder nor lightning the whole day. No such stone is known in the country, and there is no volcano nearer than Vesuvius or Hecla. The constituent parts of this stone were found exactly the same as those of the stones from Benares.*

On the 26th of April, 1803, an extraordinary shower of stones happened at L'Aigle, in Normandy. About one o'clock, the sky being almost serene, a rolling noise like that of thunder was heard, and a fiery globe of uncommon splendour was seen, which moved through the atmosphere with great rapidity. Some moments after there was heard at L'Aigle, and for thirty leagues round in every direction, a violent explosion, which lasted five or six minutes; after which was heard a dreadful rumbling like the beating of a drum. In the whole district there was heard a hissing noise like that of a stone discharged from a sling, and a great many mineral masses, exactly similar to those distinguished by the name of *meteor stones*, were seen to fall. The largest of these stones weighed seventeen pounds and a half. The Vicar of St. Michael's observed one of the stones fall with a hissing noise at the feet of his niece in the courtyard of his parsonage, and that it rebounded more than a foot from the pavement. When it was taken up and examined, it was found to resemble the others in every respect. As a wire manufacturer was working with his men in the open air, a stone grazed his arm and fell at his feet, but it was so hot that, on attempting to take it up, he instantly let it fall again. The celebrated Biot was deputed by government to repair to the spot and collect all the authentic facts in relation to this phenomenon, an account of which was afterward published in a long memoir. He found that almost all the residents of twenty hamlets declared that they were eyewitnesses of the shower of stones which was darted from the meteor. The interior parts of these stone resembled those of all the meteorites analyzed by Messrs. Howard and Vanquelin, such as those described above. They all contain silica, magnesia, oxyd of iron, nickel, and sulphur, in various proportions. Their specific gravity is about three and one-third or three and one-half times heavier than water.

The following are a few brief statements in relation to this subject. In 1492, November 7, a stone of 260 lib. fell at Ensisheim, in Alsace. It is now in the library of Colmar, and has been reduced to 150 lib., in consequence of the abstraction of fragments. The famous Gassendi relates that a stone of a black metallic colour fell on Mount Vaision, in Provence, November 29, 1637. It weighed 54 lib., and had the size and shape of the human head. Its specific gravity was three and one-half times that of water. 1654, March 30: A small stone fell at Milan and killed a Franciscan. 1706, June 7: A stone of 72 lib. fell at Larissa, in Macedonia; it smelled of sulphur, and was like the scum of iron. 1751, May 26: Two masses of iron, of 71 lib. and 16 lib., fell in the district of Agram, the capital of Croatia. The largest of these is now in Vienna. 1790, July 24: A great shower of stones fell at Barbotan, near Roquefort, in the vicinity of Bourdeaux. A mass, fifteen inches in diameter, penetrated a hut and killed a herdsman and a bullock. Some of the stones weighed 25 lib., and others 30 lib. July, 1810: A large ball of fire fell from the clouds at Shahabad, which burned five villages, destroyed the crops, and killed several men and women. November 23, 1810: Three stones fell in the commune of Charionville and neighbourhood of Orleans. These stones were precipitated perpendicularly, and without the appearance of any light or ball of fire. One of them weighed 20 lib.

* See a long paper on this subject, by E. Howard, Esq., F.R.S., in "Transactions of the Royal Society of London" for 1802.

and made a hole in the ground in a perpendicular direction, driving up the earth to the height of eight or ten feet. It was taken out half an hour after, when it was still so hot that it could scarcely be held in the hand. The second formed a hole three feet deep, and weighed 40 lib. 1812, April 15: A stone, the size of a child's head, fell at Erxleben, and a specimen of it is in the possession of Professor Haussmann, of Brunswick. 1814, September 1: A few minutes before midday, while the sky was perfectly serene, a violent detonation was heard in the department of the Lot and Garonne. This was followed by three or four others, and finally by a rolling noise at first resembling a discharge of musketry, afterward the rumbling of carriages, and, lastly, that of a large building falling down. Stones were immediately after precipitated to the ground, some of which weighed 18 lib., and sunk into a compact soil to the depth of eight or nine inches, and one of them rebounded three or four feet from the ground. 1818, July 29, O. S.: A stone of 7 lib. weight fell at the village of Slobodka, in Russia, and penetrated nearly sixteen inches into the ground. It had a brown crust with metallic spots. In 1825, February 10: A meteoric stone, weighing 16 lib. 7 oz., fell from the air at Nanjemoy, Maryland. It was taken from the ground about half an hour after its fall, was sensibly warm, and had a sulphureous smell.

Several hundreds of instances similar to the above might be produced of large masses of stones having fallen from the upper regions upon the earth.* These stones, although they have not the smallest analogy with any of the mineral substances already known, either of a volcanic or any other nature, have a very peculiar and striking analogy with each other. They have been found at places very remote from each other, and at very distant periods. The mineralogists who have examined them agree that they have no resemblance to mineral substances, properly so called, nor have they been described by mineralogical authors. They have, in short, a peculiar aspect, and peculiar characters which belong to no native rocks or stones with which we are acquainted. They appear to have fallen from various points of the heavens, at all periods, in all seasons of the year, at all hours both of the day and night, in all countries in the world, on mountains and on plains, and in places the most remote from any volcano. The luminous meteor which generally precedes their fall is carried along in no fixed or invariable direction; and as their descent usually takes place in a calm and serene sky, and frequently in cloudless weather, their origin cannot be traced to the causes which operate in the production of rain, thunder-storms, or tornadoes.

From a consideration of these and many other circumstances, it appears highly probable, if not absolutely certain, that these substances proceed from regions far beyond the limits of our globe. That such solid substances, in large masses, could be generated in the higher regions of the atmosphere, is an opinion altogether untenable, and is now generally discarded, even by most of those philosophers who formerly gave it their support. That they have been projected from volcanoes is a hypothesis equally destitute of support; for the products of volcanoes are never found at any great distance from the scene of their formation, and the substances they throw out are altogether different in their aspect and composition from meteoric stones. Besides, these stones, in most instances, have descended to the earth in places removed hundreds, or even thousands of miles from any volcanic mountain, and at times when no remarkable eruption was known to take place. Perceiving no probability of their having their origin either in the earth or the atmosphere, Dr. Hutton, Poisson, La Place, and others, conjectured that they were projected from the moon. They demonstrated the abstract proposition, that a heavy body projected with a velocity of six thousand feet in a second may be carried beyond the sphere of the moon's attraction, and come within the attraction of the earth. But it has never yet been proved that volcanoes exist on the surface of the moon; and, although they did exist, and were as large and powerful as terrestrial volcanoes, they would have no force sufficient to carry large masses of stone with such a rapid velocity over a pace of several thousands of miles. Besides, were the moon the source of meteoric stones, ejected from the craters of volcanoes, we should expect such volcanic productions to exhibit several varieties of aspect and composition, and not the precise number of ingredients which are always found in meteoric stones. From a consideration of the difficulties attending this hypothesis, La Place was afterward induced to change his opinion.

In order to trace the origin of meteoric stones, we are therefore under the necessity of directing our views to regions far beyond the orbit of the moon. On the supposition that the bursting of a large planet was the origin of the small planets Vesta, Juno, Ceres, and Pallas, we may trace a source whence meteoric stones probably originate. "When

* For more particular details on this subject, the reader may consult "The Edinburgh Encyclopædia," art. *Meteorite*. The "Edin. Phil. Journal," No 2, p. 221-255. "Phil. Magazine," vol. xiii. "Retrospect of Philosophical Discoveries," 1805, vol. i. p. 201-210, &c. &c.

the cohesion of the planet was overcome by the action of the explosive force, a number of little fragments, detached along with the greater masses, would, on account of their smallness, be projected with very great velocity; and, being thrown beyond the attraction of the greater fragments, might fall towards the earth when Mars happened to be in the remote part of his orbit. When the portions which are thus detached arrive within the sphere of the earth's attraction, they may revolve round that body at different distances, and may fall upon its surface, in consequence of a diminution of their centrifugal force; or, being struck by the electric fluid, they may be precipitated upon the earth, and exhibit all those phenomena which usually accompany the descent of meteoric stones." This opinion appears to have been first broached by Sir David Brewster, and is stated and illustrated in the "Edinburgh Encyclopædia," article *Astronomy*, and in vol. ii. of his edition of "Ferguson's Astronomy." Though not unattended with difficulties, it is perhaps the most plausible hypothesis which has yet been formed to account for the extraordinary phenomena of heavy substances falling with velocity upon the earth through the higher regions of the atmosphere.

On this subject I would consider it as premature to hazard any decisive opinions. I have laid down the above facts before the reader that he may be enabled to exercise his own judgment and form his own conclusion. I have stated them particularly with this view, that they may afford a subject of investigation and reflection. For all the works and dispensations of the Almighty, both in the physical and moral world, are worthy of our contemplation and research, and may ultimately lead both to important discoveries and to moral instruction. Though "the ways of God" are, in many instances, "past finding out," yet it is our duty to investigate them so far as our knowledge and limited powers will permit. For as we are told, on the highest authority, that "the works of the Lord are great and marvellous," so it is declared that "they will be sought out" or investigated "by all those who have pleasure therein." There is, perhaps, no fact throughout the universe, however minute in itself, or however distant from the scene we occupy, but is calculated, when properly considered, to convey to the mind an impression of the character of the Deity and of the principles of his moral government. The mere philosopher may content himself with the application of the principles of chymistry and mathematics to the phenomena of matter and motion; and it is highly proper and necessary that both chymical and mathematical analysis be applied for the investigation of the laws and order of the material universe; but the man who recognizes the principles of Divine Revelation will rise to still higher views. From nature he will ascend to nature's God, and trace the invisible perfections of the Eternal from the visible scene of his works; and, from his physical operations, will endeavour to learn something of the order and economy of his *moral* administration.

If there be any foundation for the hypothesis to which we have adverted, it might be a question and a subject of consideration at what period the disruption of the supposed planet may have taken place. If the history of the fall of meteoric stones would be considered as throwing any light on this question, it will follow that such an event must have taken place at a very distant period: for the descent of such stones can be traced back to periods more than a thousand years before the commencement of the Christian era; perhaps even to the days of Joshua, when a shower of stones destroyed the enemies of Israel,* which would lead us to conclude that more than three thousand years must have elapsed since such an event. It might likewise be a subject of inquiry, why the Deity has exposed the earth to the impulse of such ethereal agents; for the fall of meteoric stones is evidently attended with imminent danger to the inhabitants of those places on which they fall. The velocity and impetus with which they descend are sufficient to cause instant death to those whom they happen to strike, and even to demolish human habitations, as happened in several of the instances above recorded. Would the Deity have permitted a world peopled with innocent beings to be subjected to such accidents and dangers? If not, is it not a presumptive proof that man, in being exposed to such casualties from celestial agents, as well as from storms, earthquakes, and volcanoes, is not in that state of primeval innocence in which he was created? And if we suppose that a moral revolution was the cause of the catastrophe which happened to the planet to which we allude, we may trace both a physical and a moral connexion, however distant, between the earth and that planet; for if the stones to which we allude are a part of the wreck of that world, they have been the means of exciting alarm among various tribes of the earth's population, and of producing destruction and devastation; so that

* These stones, in our translation of the Bible, are called *hailstones*, but without any reason, since the original word, *abenim*, signifies stones in general according to the definition given in Parkhurst's Hebrew Lexicon; and in the book of Job, chap. xxviii. 3, the word is translated *stones of darkness*; meaning, undoubtedly, metallic stones or metals which are searched out from the bowels of the earth.

one depraved world has been the instrument in some degree of punishing another.

But perhaps I have gone too far in such speculations. I have stated them with the view of showing that we might occasionally connect our moral views of the Deity with the contemplation of the material fabric of the universe. When, through the medium of our telescopes and our physical investigations, we obtain a glimpse of the order and economy of a distant region of the universe, it may be considered as a new manifestation of the Deity, and it is our duty to deduce from it those instructions it is calculated to convey. And although we may occasionally deduce erroneous conclusions from existing facts, yet such speculations and reflections may sometimes have a tendency to excite an interesting train of thought, and to inspire us with an ardent desire of beholding the scene of the universe and the plan of the Divine administration more completely unfolded, in that world where the physical and moral impediments which now obstruct our intellectual vision shall be for ever removed.

### VI. ON THE PLANET JUPITER.

Next to Pallas, in the order of the system, is the planet Jupiter. This planet, when nearest the earth, is the most splendid of all the nocturnal orbs, except Venus and the moon. Its distance from the sun is 495,000,000 of miles, and the circumference of its orbit, 3,110,000,000 of miles. Around this orbit it moves in eleven years and three hundred and fifteen days, at the rate of nearly thirty thousand miles every hour. When nearest to the earth, at the time of its opposition to the sun, it is about 400,000,000 of miles distant from us. A faint idea of this distance may be acquired by considering that a cannon-ball, flying five hundred miles every hour, would require more than ninety-one years to pass over this space; and a steam-carriage, moving at the rate of twenty miles an hour, would require nearly two thousand three hundred years before it could reach the orbit of Jupiter. When at its greatest distance from the earth, about the time of its conjunction with the sun, this planet is distant from us no less than 590,000,000 of miles; yet its apparent size, in this case, does not appear very much diminished, although it is 190,000,000 of miles further from us in the latter case than in the former. When viewed with a telescope, however, it appears sensibly larger and more splendid at the period of its opposition than when near the point of its conjunction.

*Diurnal Rotation.*—This planet has been found to revolve around its axis in the space of nine hours, fifty-five minutes, and forty-nine and a half seconds. This discovery was made by observing a small spot in one of the belts, which appeared gradually to move across the disk of the planet. Mr. Hook appears to have first observed it in the year 1664; and in the following year, 1665, Cassini, that accurate observer of the heavens, perceived the same spot, which appeared round, and moved with the greatest velocity when in the middle, but was narrower and moved more slowly as it approached nearer the edge of the disk, which showed that the spot adhered to the body of Jupiter, and was carried round upon it. This spot continued visible during the following year, so that Cassini was enabled to determine the period of Jupiter's rotation to be nine hours and nearly fifty-six minutes. This rotation is far more rapid than that of any of the other planets, so far as we know, and nearly equals the velocity of Jupiter in his annual course round the sun. The circumference of this planet is 278,600 miles, and, therefore, its equatorial parts will move with a velocity of 28,000 miles an hour, which is 3000 miles more than the equatorial parts of the earth's surface move in twenty-four hours. This rapid velocity of the tropical regions of Jupiter, and of the places which lie adjacent to them, will have the effect of rendering all bodies *lighter* than they would be were the motion of rotation as slow as that of the earth. The gravity of bodies at the surface of Jupiter is more than twice as great as at the surface of the earth, on account of his superior bulk; so that a body weighing one pound at the equatorial surface of the earth would weigh two pounds four ounces and a half at the surface of Jupiter. If, therefore, we were transported to the surface of that planet, we should be a burden to ourselves, being pressed down with more than double our present weight, and having but the same strength to support it. But Jupiter is *eleven* times larger in circumference than the earth; and hence, if both planets revolved on their axes in the same time, the centrifugal force on Jupiter would be eleven times greater than with us. But the squares of the number of revolutions performed in the same time by the earth and Jupiter; that is, the square of twenty-four hours, and the square of nine hours, fifty-six minutes, are nearly as one to six; therefore, a body placed on Jupiter will have sixty-six* times a greater centrifugal force than with us, which would sensibly relieve the weight of the inhabitants if they stood in need of it. This rapid rotation would of itself relieve them of one-eighth or one-ninth of their whole weight; or, in other words, a body weighing eight stone at the equator of Jupiter, if the planet stood still,

* That is, 11×6=66.

would gravitate with a force of only seven stone on the commencement of its diurnal rotation, at the rate at which we now find it.

It may perhaps be surmised by some that, since the semi-diameter of Jupiter is eleven times greater than that of the earth, the attraction or weight of bodies on its surface ought to be eleven times greater than on the surface of our globe. This would be the case if the matter in Jupiter were as dense as in the earth; and the weight of bodies would, of course, be in proportion to their semi-diameter, or the distance of the surface from the centres of these bodies. But the density of Jupiter is only a little more than that of water, while the density of the earth is five times greater. If the density of Jupiter were as great as that of the earth, and, consequently, the weight of bodies on its surface eleven times greater, men of our stature and make could scarcely be supposed to support eleven times the weight of such bodies as ours, but behooved to be almost chained down to the surface of the planet by their own gravity; and were we to suppose them of a larger stature, this inconvenience would become the greater; for the least of any species of animated beings have generally the greatest nimbleness and agility of motion. This circumstance is perhaps one of the reasons why the larger planets of the system have the least degree of density: for if Jupiter were composed of materials as dense as those of Mercury, organized beings like man would be unable, without a supernatural power, to traverse the surface of such a planet.

In consequence of the rapid motion of Jupiter, the days and nights will be proportionably short. The sun will appear to move through the whole celestial hemisphere, from the eastern to the western horizon, in less than five hours, and all the planets and constellations will appear to move with the same rapidity: so that the apparent motions of all these bodies will be perceptible to the eye when contemplating them only for a few moments, excepting those which appear near the polar regions. The sky of this planet will therefore assume an air of sublimity superior to ours, in consequence of all the bodies it contains appearing to sweep so rapidly around, and to change their positions in so short a space of time. As Jupiter moves round the sun in 4332½ of our days, and round its axis in nine hours, fifty-six minutes, there will be 10,470 days in the year of that planet.

*Magnitude and Superficial Contents of the Globe of Jupiter.*—This planet is the largest in the system, being 89,000 miles in diameter, and, consequently, *fourteen hundred times* larger than the earth. Its surface contains 24,884,000,000, or twenty four thousand eight hundred and eighty-four millions of square miles, which, at the rate of population formerly stated, 280 inhabitants to a square mile, would be sufficient for the accommodation of 6,967,520,000,000, or nearly *seven billions* of inhabitants, which is more than *eight thousand seven hundred times* the present population of our globe, and nearly *fifty* times the number of human beings that have existed on the earth since its creation. Although the one half of this planet were covered with water, which does not appear to be the case, it would still be ample enough to contain a population more than four thousand times larger than that of our globe. If such a population actually exist, as we have little reason to doubt, it may hold a rank, under the Divine government, equal to several thousands of worlds such as ours. Such an immense globe, replenished with such a number of intellectual beings, revolving with such amazing rapidity round its axis, moving forward in its annual course 30,000 miles every hour, and carrying along with it four moons larger than ours to adorn its firmament, presents to the imagination an idea at once wonderful and sublime, and displays a scene of wisdom and omnipotence worthy of the infinite perfections of its Creator.

*Discoveries which have been made in relation to Jupiter by the Telescope.*—Jupiter presents a splendid and interesting appearance when viewed with a powerful telescope. His surface appears much larger than the full moon to the naked eye; his disk is diversified with darkish stripes; his satellites appear sometimes in one position and sometimes in another, but generally in a straight line with each other. Sometimes two of them are seen on one side of the planet and two on another; sometimes two only are visible, while the other two are eclipsed either by the disk or the shadow of Jupiter; and sometimes all the four may be seen on one side and in a straight line from the planet, in the order of their distances, so that these moons present a different aspect and relation to each other every successive evening.

These moons were first seen by Galileo, in the year 1610, by means of a telescope he had constructed, composed of two glasses, a concave next the eye and a convex next the object, which magnified about thirty-three times. No further discoveries were made in relation to this planet till about the year 1633, when the *belts* were discovered by Fontana Rheita, Riccioli, and several others. They were afterward more particularly observed and delineated by Cassini. These belts appear like dark stripes across the disk of the planet, and are generally parallel to one another and to the planet's equator. They are somewhat

variable, however, both as to their number and their distance from each other, and sometimes as to their position. On certain occasions *eight* have been seen at a time; at other times only one. Though they are generally parallel to one another, yet a piece of a belt has been seen in an oblique position to the rest, as in Fig. 49. They also vary in breadth; for one belt has been observed to have grown a good deal narrower than it was, when a neighbouring belt has been increased in breadth, as if the one, like a fluid, had flowed into the other. In favour of this opinion, it is stated in the "Memoirs of the Royal Academy of Sciences" that a part of an oblique belt was observed to lie so as to form a communication between them, as represented in Fig. 49. At one time, says Dr. Long, the belts have continued without sensible variations for nearly three months; at another time a new belt has been formed in an hour or two. They have sometimes been seen broken up and distributed over the whole face of the planet, in which state they are exhibited in some of the delineations of Sir W. Herschel; but this phenomenon is extremely rare, and does not appear to have been noticed by any other observer. In the year 1787 Schroeter saw two dark belts in the middle of Jupiter's disk; and near to them two white and luminous belts, resembling those which were seen by Campani in 1664. The equatorial zone which was comprehended between the two dark belts had assumed a dark gray colour, bordering upon yellow. The northern dark belt then received a sudden increase of size, while the southern one became partly extinguished, and afterward increased into an uninterrupted belt. The luminous belts also suffered several changes, growing sometimes narrower, and sometimes one half larger than their original size.

The following figures represent some of the appearances of the belts of Jupiter.

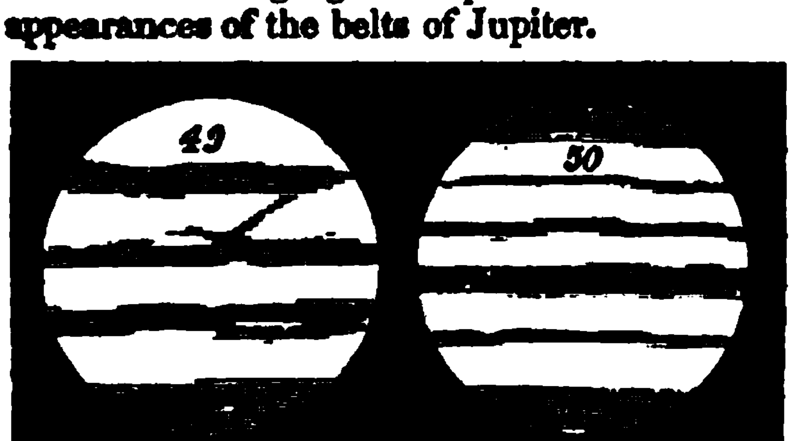
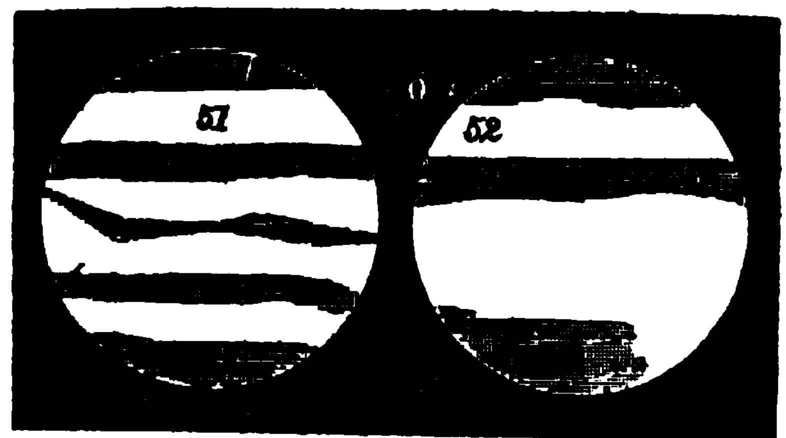
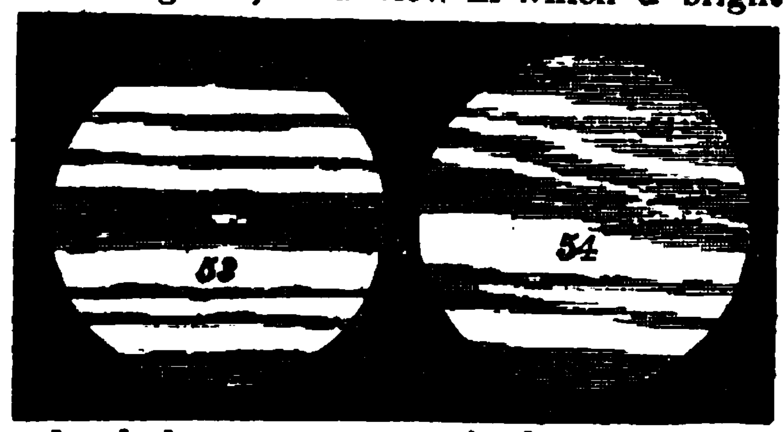



Fig. 49, represents a view of Jupiter's belts by Cassini. Fig. 50, a view from Dr. Hook, as delineated in the "Philosophical Transactions" for 1666, which was taken by a sixty feet refracting telescope. The small black spot on the middle belt, which did not appear at the beginning of the observation, and which moved about a third or fourth part across the disk in the space of ten minutes, was judged to be the shadow of one of the satellites moving across the disk of the planet. Fig. 51, exhi-




bits a view of Jupiter as he appeared about the end of 1832 and beginning of 1833, which was taken by means of an achromatic telescope, with magnifying powers of 150 and 180 times. Fig. 52, is a view taken with the same telescope in 1837. In this view the principal belt near the planet's equator appeared dark, distinct, and well defined; but the other two belts at either pole were extremely faint, and could only be perceived after a minute inspection. Fig. 53, is a view in which a bright




and a dark spot were perceived on one of the belts; and Fig. 54, a view by Sir John Herschel. I have had an opportunity of viewing Jupiter with good telescopes, both reflecting and achromatic, for twenty or thirty years past; and, among several hundreds of observations, I have never seen above four or five belts at one time. The most common appearance I have observed is that of two belts, distinctly marked, one on each side of the planet's equator, and one at each pole, generally broader, but much fainter than the others. I have never perceived much change in the form or position of the belts during the same season, but in successive years a slight degree of change has been perceptible, some of the belts having either disappeared, or turned much fainter than they were before, or shifted somewhat their relative positions; but I have never seen Jupiter without at least two or three belts. Some of the largest of these belts, being at least the one eighth part of the diameter of the planet in breadth, must occupy a space at least 11,000 miles broad and 278,000 miles in circumference; for they run along the whole circumference of the planet, and appear of the same shape during every period of its rotation. It is probable that the smallest belts

we can distinctly perceive by our telescopes are not much less than a thousand miles in breadth.

What these belts really are has been a subject of speculation and conjecture among astronomers, but it is difficult to arrive at any definite conclusion. By some they have been regarded as immense strata of clouds in the atmosphere of Jupiter; while others imagine that they are the marks of great physical changes which are continually agitating the surface of this planet. I am inclined to think that the dark belts are portions of the real surface of the planet, and that the brighter parts are something analogous to clouds, or other substances with which we are unacquainted, floating in its atmosphere, at a considerable elevation above its surface. That the dark belts are the body of the planet appears highly probable from this consideration, that the spot by which the rotation of Jupiter was determined has been always found in connexion with one of the dark belts; and as this spot must be considered as a permanent one on the body of Jupiter, so the belt with which it is connected must be considered as a portion of the real body of the planet. It is absurd and preposterous to suppose, as some have done, that the changes on the surface of Jupiter are produced by physical convulsions, occasioned by earthquakes and inundations; for, in such a case, the globe of Jupiter would be unfit for being the peaceful abode of rational inhabitants. What should we think of a world where 5000 miles of ocean occasionally inundated a corresponding portion of the land, or where earthquakes sometimes swallowed up continents of several thousands of miles in length and breadth? Such physical catastrophes recurring every year on such a splendid and magnificent globe as Jupiter would not only render it unfit for the habitation of any beings, but would imply a reflection on the wisdom and benevolence of the great Creator. Whatever opinions, therefore, we may adopt respecting the phenomena of this planet, they ought to be such as are consistent with the idea of a habitable world and with the perfections of the Deity. Were the belts of Jupiter permanent and invariable, it would be comparatively easy to account for the phenomena which appear on his surface; for the dark belts might be considered as seas, and the brighter portions of his surface as land. But as these belts, whether bright or dark, are found to be variable, we must have recourse to another hypothesis for their explanation, or be content in the mean time to confess our ignorance. Our opinions and conjectures respecting the circumstances of other worlds are too frequently guided merely by what we know of the objects and operations which exist on our globe; and we are apt to think that the arrangements of other globes destined for the abode of intellectual beings must be similar to those of our own. We talk of physical convulsions, earthquakes, and inundations in Jupiter, and of volcanic eruptions in the sun and moon, as if these phenomena were as common in other worlds as in the earth; whereas it is not improbable that they are *peculiar* to our globe, and that they are connected with the moral, or rather *demoralized* state of its present inhabitants. There is an *infinite variety* in the system of nature; and it is highly probable that there is no world in the universe that exactly resembles another. Although Jupiter moves round the sun, and turns upon his axis by the same laws which direct the motions of our globe, yet there may be as great a difference in the arrangements connected with this planet and those of the earth, as there is between the constitution of the earth and that of a planet which revolves around the star Sirius. Would it be altogether improbable to suppose that the globe of Jupiter is partly inclosed within a sphere of semitransparent substance, at a considerable elevation above his surface, or rather within parallel rings, like an Armillary sphere composed of such a substance, which vary their position, and sometimes surround one part of his globe and sometimes another? These rings, of whatever substance they might be composed, might serve to reflect the rays of the sun so as to produce an addition of light and heat, and, at the same time, by exhibiting a variety of colours and motions, to diversify and adorn the firmament of this planet. Almost any supposition is preferable to the idea of a continued scene of physical convulsions. The idea now thrown out is not more extravagant than that of a planet nearly as large as Jupiter being surrounded with two concentric rings. Had we not discovered the rings of Saturn, we should never have formed the idea of a world environed with such an appendage. As a corroboration of the idea that the bright stripes which appear on this planet surround its body at a considerable elevation, it has been observed by Sir John Herschel, "that the dark belts do not come up in all their strength to the edge of the disk, but fade away gradually before they reach it;" an almost decisive proof that the bright belts inclose the dark ones, or, in other words, the body of the planet; and that they are elevated above the dark globe of Jupiter, in all probability, not less than a thousand miles.

Whatever opinion we may form as to the constitution of this planet, the phenomena it presents afford a vast field for investigation and reflection. If it be a fact, as has been asserted by credible observers, that two belts

have gradually disappeared during the time of an observation, and that, at another time, a new belt has been formed in an hour or two, agents far more powerful than any with which we are acquainted must have been in operation to produce such an effect, and changes more extensive than any which take place in our terrestrial sphere must have happened in the regions connected with Jupiter; for some of the belts of this planet are from five to ten thousand miles in breadth; and if those alluded to extended quite across the disk of the planet, they must have been more than one hundred and thirty thousand miles in length. Yet such a change may have taken place, not only without convulsions, causing terror and confusion, but to the admiration and joy of the inhabitants of that globe, as opening up a new and striking scene in the canopy of heaven; for if we suppose such bright belts or circles as we have imagined rapidly to shift their position in the canopy above, such a grand effect might in a short time be produced.

Besides the belts, spots of different kinds, some of them brighter and some darker than the belts, have been occasionally seen. The spot by which Jupiter's rotation was determined is the largest, and of the longest continuance of any hitherto observed. Its diameter is one tenth of the diameter of Jupiter, and it is situated in the northern part of the southern belt. Its centre, when nearest that of the planet, is distant from the centre of Jupiter about one third of the semidiameter of the planet. This spot was first perceived by Hook and Cassini in the years 1664, 1665, and 1666. It appeared and vanished eight times between the year 1665 and 1708. From 1708 till 1713 it was invisible; the longest time of its continuing to be visible was three years, and the longest period of its disappearing was from 1708 to 1713. It has evidently some connexion with the southern belts; for it has never been seen when that disappeared, though that belt has often been visible without the spot. Besides this ancient spot, as it is called, Cassini, in the year 1699, saw one of less stability, which did not continue of the same shape and dimensions, but broke into several small ones, of which the revolution was but 9 hours, 51 minutes; and two other spots which revolved in 9 hours, 52½ minutes. The large spot described above, being about the one tenth of the diameter of Jupiter, must have been more than 8000 miles in extent, and, consequently, larger than the diameter of the earth. When Cassini had assured himself of the period of rotation from the motion of this spot, he made a report of his observations to the Royal Academy of Sciences, and calculated the precise moment when the spot would appear on the eastern limb of the planet, on a future day; on which the academy sent a deputation of M. Buot, M. Mariotte, and others, to be present at the observation; and when they came to the royal observatory, they saw the spot in the position predicted, and traced its motion for an hour or two, till the heavens began to be overcast with clouds. All the observations which have been made upon this spot and others, and its successive appearance and disappearance, perfectly agree with the idea of bright belts inclosing the globe of Jupiter at a distance from the surface, and varying their aspect and motions at different periods of time. And although some readers may consider it as a trifling matter to dwell with such particularity on a spot in Jupiter, yet that spot, however insignificant it may appear through our telescopes, may be more spacious and important in the system of nature than all the continents and islands of our globe, and may form a greater portion of the divine government than all the kingdoms of the earth.

There is a peculiar splendour in the appearance of Jupiter, both through the telescope and to the naked eye, considering his great distance from the sun and from the earth. The planet Mars appears comparatively dull and obscure, even when nearest the earth, when it is only fifty millions of miles distant; while the planet Jupiter, which is 350 millions of miles further from the earth and from the source of light, presents a brilliancy of aspect far superior. This circumstance seems to indicate that there is some apparatus connected with the globe of Jupiter calculated to reflect the light of the sun in a peculiar manner, both on the surface of the planet itself, on its moons, and towards other planets. Such an apparatus is not only consistent with the supposition thrown out above, but tends to corroborate it; and however strange we may consider the idea of brilliant belts surrounding a planet, yet as *variety* is stamped on all the works of the Creator, and as no world is precisely like another, the dissimilarity of such an appendage to what we know of our own or of other globes ought to be no argument against its existence. If we wish to know more of the phenomena of this planet than what we have hitherto ascertained, we must endeavour to improve our telescopes, and to increase, indefinitely, the number of observers. Were an immense number of intelligent observers distributed over different parts of the earth, and provided with the best telescopes; were they to mark with care and minuteness the phenomena to which we have adverted; were they to delineate, in a series of drawings, the various aspects of this planet during two or three periodical revolutions, marking the periods of the different changes, and the positions of the

planet with respect to the earth and the sun, and noting at the same time the positions of the satellites when any change in the belts took place, we might possibly ascertain something more of the nature of the belts, whether dark or bright, of the periods of their changes, and whether these changes be influenced by the attractive power of the satellites. For if any appendage is connected with Jupiter composed of a substance of small density, it is reasonable to believe that its positions and movements would be affected at certain times by the positions of the satellites, especially when they all happened to be situated on the same side of Jupiter.

*Seasons, Proportion of Light, &c., in Jupiter.*—The axis of this planet being nearly perpendicular to the plane of its motion, there can be no variety of seasons similar to what we experience. The inclination of its axis, however, is stated by some astronomers to be 86 degrees, 54½ minutes; or 3 degrees, 5½ minutes from the perpendicular. This inclination will cause a slight variety of seasons at different periods of the planet's annual revolution, but not nearly to the same extent as in Mars or the earth. If the axis of Jupiter were as much inclined to his ecliptic as the axis of the earth, his polar regions would remain in darkness for nearly six years without intermission, just as the places around our north and south poles are deprived of the light of the sun for one half of the year. There will be nearly equal day and night in every part of the surface of this planet; but to the places near the equator the sun will appear to rise to a high elevation above the horizon, and to move through the heavens with great rapidity, while near the polar regions he will appear to move comparatively slow, and to describe only a small semicircle above the horizon. We are not to imagine, however, that "everlasting winter" prevails around the poles of this planet, as some have asserted, because the sun never rises high above those regions, and the solar rays fall obliquely upon them; for there may be arrangements and compensations, of which we are ignorant, to produce nearly as great a degree of light and heat in the polar as in the equatorial regions; and perhaps the bright belts to which we have adverted may be so arranged as to contribute to this effect. Nor are we to imagine that there is no *variety of scenery* in Jupiter because there are no seasons similar to ours. For every degree of latitude from the equator to the poles will produce a diversity of aspect; and the variation of the belts, whatever may be their arrangement, and of what substances soever they may consist, will produce a diversity of scenery in the firmament of Jupiter far greater, and, perhaps, far more magnificent and transporting than any thing we contemplate in our terrestrial abode.

The *intensity of the solar light* on the surface of Jupiter is twenty-seven times less than on the earth. The mean apparent diameter of the sun, as seen from the earth, is thirty-two minutes, three seconds; but the solar diameter, as seen from Jupiter, is only six minutes, nine seconds, which is less than one fifth so great as the sun appears to us. The square of 6′ 9″, or 369″, is 136,161, and the square of 32′ 3″ is 369,729, which, divided by 136,161, produces a quotient of 27 1-6, which shows that the surface of the sun, as seen from Jupiter, is more than twenty-seven times less than he appears to us; and as the intensity of light decreases in proportion to the square of the distance, there will be twenty-seven times less light on this planet than on the earth. But if the intensity of the light be increased by reflection from any substances connected with this planet, or if the inhabitants have the pupils of their eyes much larger than ours, all the objects around them may appear with even greater splendour than on the earth. The following figures will show to the eye the proportional size of the sun as seen from Jupiter and from the earth. The small circle shows the comparative bulk of the solar orb as seen from Jupiter, and the larger circle its bulk as viewed from the earth.

Fig. 55.



Nothing particular has been ascertained respecting an *atmosphere* surrounding this planet. Though it is probable that it has an appendage answering the purpose of an atmosphere, yet it may be very different in its nature and properties from that which surrounds the earth. And if the planet be surrounded with bright belts, as we have supposed, or if the bright parts of its surface are to be considered as something analogous to clouds suspended in a body of air, it is evident that the denser parts of its atmosphere never can be perceived by us, and that no dimness or obscurity is to be expected when a fixed star approaches its disk. Hence M. Schroeter, when he had a very clear and distinct view of the spots and belts when Jupiter suffered an

occultation by the moon on the 7th of April, 1792, could perceive nothing throughout the whole observation indicative of a refractive medium near the margin of the planet.

Jupiter is remarkable on account of his *spheroidal figure.* This figure is obvious to the eye when viewing the planet with a high magnifying power. Nor is this an optical illusion; for both diameters have been accurately measured by the micrometer; and the equatorial diameter is found to be in proportion to the polar nearly as fourteen to thirteen, so that the equatorial is more than 6300 miles longer than the polar diameter. This oblate figure is ascribed to the swiftness of Jupiter's rotation, which produces a centrifugal force, which has a tendency to make the equatorial parts more protuberant than the polar. From calculations formed on the principles of physical astronomy, it is found that the proportion above stated is really the degree of oblateness which corresponds, on those principles, to the dimensions of this planet and the time of its rotation; so that theory perfectly harmonizes with observation.

The *density* of this planet compared with that of water is as 1 1-24 to 1; that is, it is a small fractional part denser than water. Its *mass*, compared with that of the sun, is as 1 to 1067; compared with that of the earth, as 312 to 1, that is, Jupiter could weigh 312 globes of the same size and density as the earth. The *eccentricity* of its orbit is 23,810,000 miles; and the *inclination* of the orbit to the ecliptic is about one degree, nineteen minutes. Its mean *apparent diameter* is thirty-eight seconds, and its greatest diameter, when in opposition to the sun, forty-seven and a half seconds. Its mean arc of retrogradation is nine degrees, fifty-four minutes, and its mean duration about 121 days. This retrogradation, or moving contrary to the order of the signs, commences or finishes when the planet is not more than 115 degrees from the sun. The following figure exhibits a view of Juniter and his satellites as seen through a good telescope.

Fig. 56.

VII. ON THE PLANET SATURN.

The planet Saturn may be considered in almost every respect as the most magnificent and interesting body within the limits of the planetary system. Viewed in connection with its satellites and rings, it comprehends a greater quantity of surface than even the globe of Jupiter; and its majestic *rings* constitute the most singular and astonishing phenomena that have yet been discovered within the limits of our system.

Its distance from the sun is 906 millions of miles, which is nearly twice the distance of Jupiter; and the circumference of its orbit is 5,695,000,000 of miles; to move round which a cannon ball would require more than 1300 years, although it were moving 500 miles every hour. But a steam-carriage, moving at the rate of twenty miles an hour, would require above 32,500 years to complete the same round. When nearest the earth, Saturn is 811 millions of miles distant, an interval which could not be traversed by a carriage, at the rate now stated, in less than 4629 years; and even a cannon ball, moving with the velocity above mentioned, would require 184 years. So that, although man were divested of the gravitating power, and capable of supporting himself amid the ethereal regions, and though he were invested with a power of rapid motion superior to any movement we perceive on earth, before he could reach the middle orbit of the planetary system, or one fourth of its diameter, it would require a space of time far more than is yet allotted to mortal existence, and, therefore, all hope of personally exploring the celestial regions is completely annihilated, so long as we are invested with our present corporeal vehicles, and are connected with this terrestrial abode.

This planet revolves around the sun in the space of about 29½ years, or in 10,756 days, 23 hours, 16 minutes, 34 seconds, which is its *sidereal* revolution, or the time it takes in moving from a certain fixed star to the same star again. Through the whole of its circuit it moves at the rate of 22,000 miles every hour. The period of its rotation was for a long time unknown. About a century ago, it was conjectured by some astronomers that it was accomplished in about ten or eleven hours. It was not, however, till Sir W. Herschel applied his powerful telescopes to Saturn that its rotation was accurately determined. By certain dark spots which he perceived on its disk, and by their change of position, he ascertained that the diurnal rotation is performed in ten hours, sixteen minutes, and nineteen seconds.* It is remarkable that La Place, from physical considerations, had calculated the rotation of Saturn to be nearly the same as above stated, before Herschel had de-

* Sir John Herschel states the period of rotation to be ten hours twenty-nine minutes, seventeen seconds.

termined it by direct observation. The rotation is performed on an axis perpendicular to the plane of the ring. The circumference of Saturn being 248,000 miles, the parts about the equator will move at the rate of 24,000 miles an hour. Its year will consist of 25,150 days, or periods of its diurnal rotation.

*Proportion of Light on Saturn.*—This planet being about 9½ times further from the Sun than the earth, it will receive only the *one ninetieth* of the light which we receive; for the square of 9½ is equal to 90¼. This quantity of light, however, is equal to the light which would be reflected from a thousand full moons such as ours; and there can be little doubt that the beings that reside in this planet have their organs of vision so constructed as to be perfectly adapted to the quantity of light they receive; and, by such an adaptation, all the objects around them may appear as splendidly enlightened, and their colours as vivid as they do on the globe on which we live. The apparent diameter of the sun, as seen from Saturn, is three minutes, twenty-two seconds; but his mean apparent diameter, as seen from the earth, is equal to thirty-two minutes, three seconds. This proportion of size in which the sun appears from the earth and from Saturn is represented in the following figure, in which the small circle represents the size of the sun as seen from Saturn.

Fig. 57.

*Discoveries by the Telescope on the Body of Saturn.*—The great distance of this planet from the earth prevents us from observing its surface so minutely as that of Jupiter. Certain dusky spots, however, have of late years been occasionally seen on its surface, when very powerful telescopes were applied, and by the motion of these its diurnal rotation was determined. Belts somewhat similar to those of Jupiter have likewise been seen. Huygens, more than 150 years ago, states that he had perceived five belts on Saturn which were nearly parallel to the equator. Sir W. Herschel, in his numerous observations, also observed several belts, which in general, were parallel with the ring. On the 11th of November, 1793, immediately south of the shadow of the ring upon Saturn, he perceived a bright, uniform, and broad belt, and close to it a broad or darker belt, divided by two narrow white streaks, so that he saw five belts, three of which were dark and two bright. The dark belt had a yellow tinge. These belts cover a larger zone of the disk of the planet than the belts of Jupiter occupy upon his surface. With a magnifying power of 200 times I have sometimes seen one darkish belt on the body of Saturn; but it was much fainter than those of Jupiter. It does not appear that these belts vary or shift their positions, as the belts of Jupiter are found to do; the dark ones are much fainter than those of Jupiter, and, therefore, it is most probable that they are permanent portions of the globe of Saturn, which indicate a diversity of surface and configuration either of land or water, or of some other substances with which we are unacquainted. When this planet is viewed with a good telescope, it appears, like Jupiter, to be of a spheroidal figure, or somewhat approaching to it The proportion of its polar to its equatorial diameter is as 32 to 35, or nearly as 11 to 12; so that the polar diameter is more than 6,700 miles shorter than the equatorial, which is a greater difference than that of the two diameters of Jupiter. Saturn was generally considered, till lately, as a regular spheroid; but on the 12th of April, 1805, Sir W. Herschel was struck with a very singular appearance when viewing the planet. "The flattening of the poles did not seem to begin till near a very high latitude, so that the real figure of the planet resembled a square, or rather a parallelogram, with the four corners rounded off deeply, but not so much as to bring it to a spheroid." It is probable that the action of the ring or its attractive power is the cause of the great protuberance which is found about the equatorial regions of Saturn.

*Magnitude and Extent of Surface on Saturn.*—This planet is about 79,000 miles in diameter, and nearly a thousand times larger than the earth. Its surface contains more than 19,600,000,000 of square miles, and, consequently, at the rate of 280 inhabitants to a square mile, it would contain a population of 5,488,000,000,000, or about five billions and a half, which is six thousand eight hundred and sixty times the present number of inhabitants on our globe; so that this globe, which appears only like a dim speck on our nocturnal sky, may be considered as equal to six thousand worlds like ours; and since such a noble apparatus of rings and moons is provided for the accommodation and contemplation of intelligent beings, we cannot doubt that it is replenished with

ten thousand times ten thousands of sensitive and rational inhabitants; and that the scenes and transactions connected with that distant world may far surpass in grandeur whatever has occurred on the theatre of our globe.

*Density of Saturn.*—The density of Saturn compared with that of the earth is nearly as one to nine; compared with that of water, it is less than one-half; so that the mean density of this planet cannot be much more than the density of cork; and, consequently, the globe of Saturn, were it placed in an immense ocean, would swim on the surface as a piece of cork or light wood swims in a basin of water. There is none of the planets, so far as we know, whose density is so small as that of Saturn, or less than the density of water. We are not to imagine, however, that the materials which compose the surface of Saturn are as light as cork, or similar substances; for any thing we know to the contrary, they may be as dense as the rocks and mould which compose the crust of our globe. We have only to suppose that the globe of Saturn is hollow, or merely filled with some elastic fluid, and that the solid parts of its exterior crust form a shell of a hundred or two hundred miles in thickness. It is true, indeed, that the density of our globe increases from its surface downward, perhaps even to the centre. But we have no reason to suppose that this is the case with all the other planets; on the contrary, it is most probable that it is exactly the reverse in the case of Saturn; for if the materials which compose that planet were to increase in density towards the centre, the substances on its surface would have little more density or solidity than that of a cloud suspended in the atmosphere. And we know that, in all the works of the Creator, *variety* is one grand characteristic of his plans, even where the same general objects are intended to be accomplished, and the same *general* laws are in operation.

From want of correct views on this subject, several foolish and erroneous notions have been entertained and circulated. In a late number of a popular and extensively circulated journal, when treating of "Planetary Arrangements," it is stated, that "while on Mercury a native of earth would scarcely be able to drag one foot after another for the strong power pulling him to the ground, he could, on the planet Saturn, leap sixty feet high as easily as he could here leap a yard." Now both these positions are quite erroneous; for although the density of Mercury is about double the density of the earth, and nearly that of lead, yet the bulk of the two planets is very different, the diameter of the earth being nearly 8000 miles, while that of Mercury is only 3200, and the force with which a body placed on their surfaces gravitates to them is in proportion to their *masses* divided by the *squares of their diameters.* If Mercury were as large as the earth, an inhabitant of our globe placed on the surface of that planet would feel himself "pulled to the ground" as if he were placed on a similar ball of lead, and his weight, of course, would be increased; but, as matters now stand, the gravitation on Mercury is only a small fraction greater than on the surface of the earth; so that, in this respect, "a native of earth," and particularly an inhabitant of Greenland, might walk with nearly as much ease on the planet Mercury as under our equator. The same considerations show the absurdity of what is stated in relation to Saturn; for that planet is ten times the diameter of the earth; and though its density is nearly as small as that of cork, yet its immense bulk renders the force of gravity at its surface somewhat greater than even on the earth, and almost as great as on the surface of Mercury. A body which weighs one pound on the surface of the earth would weigh one pound and four drachms if removed to the surface of Saturn; so that a person, instead of being able to "leap sixty feet high" from the surface of this planet, would be unable to leap quite so high as he can do on the earth. In short, there is not a planet in the solar system, with the exception of Jupiter, on which an inhabitant of the earth might not move about as easily, in respect to gravitating power, as he does on the terraqueous globe; and even on Jupiter he would experience little more than double the weight he now feels. On some of the other planets, such as Mars and Juno, he would feel somewhat lighter than he now does, but not nearly so much as would enable him to leap to such a height as above stated. On the same principle, which is taken for granted in the above quotation, we might suppose that a person would feel much lighter were he placed on the surface of the sun, because the density of that luminary is little more than the density of water; whereas, in consequence of his immense size, the gravitating power would be *twenty-seven* times greater than at the surface of our globe. For, according to the calculations of La Place, a body which, at the earth's equator, weighs one pound, if transported to the surface of the sun would weigh about twenty-seven and a half pounds; from which it follows, that there a heavy body would descend about four hundred and twenty-five feet in the first second of time; consequently, were a man who weighs two hundred pounds to be placed on the sun, he would be pressed down to its surface with a force equal to five thousand five hundred pounds, or nearly two tons and a half, which would fix him to the surface without power

of motion. So that whatever beings may inhabit that globe, it is not fitted for the residence of man in his present state of organization.

The *eccentricity* of Saturn's orbit is 49,000,000 of miles, which is about the 1-37 part of the diameter of the orbit. Its inclination to the ecliptic is 2° 29½'. Its apparent diameter, as seen from the earth, is seventeen minutes, six seconds; and its mean daily motion, two minutes of a degree.

### VIII. ON THE RINGS OF SATURN.

Besides the appearances above described, this planet is encircled with a double ring, one of the most astonishing phenomena which have yet been discovered in the heavens, and which, therefore, requires a separate and particular description.

The first individual who perceived a glimpse of Saturn's ring was Galileo, soon after the invention of the telescope. He thought he saw that planet appear like two smaller globes on each side of a larger globe; or, as he expressed it, that "Saturn was in the shape of an olive." In the year 1610 he published his discovery in a Latin sentence, the meaning of which was, that he had seen Saturn appear *with three bodies.* After viewing Saturn in this form for two years, he was surprised to see him become quite round without his adjoining globes, and to remain in this state for some time, and, after a considerable period, to appear again in his triple form as before. This deception was owing to the want of magnifying power in the telescope used by Galileo; for the first telescope constructed by this astronomer magnified the diameters of objects only three times; his second improved telescope magnified only eight times; and the best telescope which, at that time, he found himself capable of constructing, magnified little more than *thirty times*; and with this telescope he made most of his discoveries. But a telescope of this power is not sufficient to show the opening or dark space between the ring and Saturn on each side of the planet; and at the time when it appeared divested of its two appendages the thin and dark edge of the ring must have been in a line between his eye and the body of Saturn, which phenomenon happens once every fifteen years. About forty years after this period the celebrated Huygens greatly improved the art of grinding object glasses; and with a telescope of his own construction, twelve feet long, and afterward with another of twenty-three feet, which magnified objects one hundred times, he discovered the true shape of Saturn's ring, and in 1659 he published his "*Systema Saturnium*," in which he describes and delineates all its appearances.

It was suspected by astronomers more than a century ago that the ring of Saturn was double, or divided into two concentric rings. Cassini supposed it probable that this was the case. Mr. Pound, in the account of his observations on Saturn in 1723, by means of Hadley's new reflecting telescope, states that with this instrument he could plainly perceive "*the black list in Saturn's ring*," and gives an engraving of the planet and ring with this dark stripe distinctly marked, as in the modern views of Saturn.* Mr. Hadley likewise states† that, in the year 1722, with the same telescope, he observed the dark line on the ring of Saturn parallel to its circumference, which was chiefly visible on the ansæ, or extremities of the elliptic figure in which the ring appears, but that he was several times able to trace it quite round; particularly in May, 1722, he could discern it without the northern limb of Saturn, in that part of the ring that appeared beyond the globe of the planet, and could perceive that the globe of Saturn reflects less light than the inner part of the ring. It was not, however, till Sir W. Herschel began to make observations on this planet with his powerful telescopes that Saturn was recognized as being invested with two concentric rings. The following cut (Fig. 58) exhibits a view of Saturn and his rings, nearly in their respective proportions, as they would appear were they placed perpendicular to our line of sight; but, on account of the oblique angle they generally form to our line of vision, we never see them through the telescope in this position.

Fig. 58.

The following are the dimensions of the rings, as determined by the observations of Sir W. Herschel, which are here expressed in the nearest round numbers. Outside diameter of the *exterior* ring, *a d*, 204,800.

* See "*Philosophical Transactions*," No. 378, for July, 1723; and Reid and Gray's Abridgment, vol. vi. p. 153.

† "*Philosophical Transactions*," No. 378; or Abridgment, vol. vi. p. 154.

miles, which is nearly twenty-six times the diameter of the earth. Inside diameter of this ring, 190,200 miles; breadth of the dark space between the two rings, 2839 miles, which is 700 miles more than the diameter of our moon, so that a body as large as the moon would have room to move between the rings. Outside diameter of the *interior* ring *b*, 184,400, and the inside diameter, 146,300 miles. *Breadth* of the exterior ring, 7200 miles; breadth of the interior 20,000 miles, or 2½ times the diameter of the earth; so that the interior ring is nearly three times broader than the exterior. The *thickness* of the rings has not yet been accurately determined. Sir John Herschel supposes that it does not exceed a hundred miles. "So very thin is the ring," says Sir John, "that it is quite invisible, when its edge is directly turned to the earth, to any but telescopes of extraordinary power." On the 19th of April, 1833, "the disappearance of the rings was complete when observed with a reflector eighteen inches in aperture and twenty feet in focal length.* The breadth of the two rings, including the dark space between them, is very nearly equal to the dark space which intervenes between the globe of Saturn and the inside of the interior ring. It appears to have been lately ascertained that this double ring is not exactly circular, but eccentric. This seems to have been first observed by M. Schwalz, of Dessau, in 1828. He informed M. Harding, of it, who thought he saw the same thing; M. Harding informed Professor Schumacher, who applied to M. Struve to settle the question by means of the superb micrometer attached to his great telescope. M. Struve measured the distance between the ring and the body of the planet on five different days, and ascertained that *Saturn's ring is really eccentric*, and, consequently, that the centre of the planet does not coincide with the centre of the ring; but that the centre of gravity of the rings oscillates round that of the body of Saturn, describing a very minute orbit. This is considered as of the utmost importance to the *stability* of the system of the rings, in preventing them from being shifted from their equilibrium by any external force, such as the attraction of the satellites, which might endanger their falling upon the planet. That this double ring really consists of two concentric rings, was demonstrated, says Professor Robinson, "by a star having been seen through the interval between them."

This double ring is now found to have a swift rotation around Saturn in its own plane, which it accomplishes in about ten hours and a half. This is very nearly the periodic time which a satellite would take in revolving at the same distance from the centre of Saturn. This rotation was detected by observing that some portions of the ring were a little less bright than others. Sir W. Herschel, when examining the plane of the ring with a powerful telescope, perceived near the extremity of its arms or *ansæ* several lucid or protuberant points, which seemed to adhere to the ring. At first he imagined them to be satellites, but afterward found, upon careful examination, that none of the satellites could exhibit such an appearance, and therefore concluded that these points adhered to the ring, and that the variation in their position arose from a rotation of the ring round its axis in the period above stated. The circumference of the exterior ring being 643,650 miles, every point of its outer surface moves with a velocity of more than a thousand miles every minute, or seventeen miles during one beat of the clock. It is highly probable that this rapid rotation of the ring is one of the principal causes, under the arrangements of the Creator, of *sustaining* the ring, and preventing it from collapsing and falling down upon the planet. This double ring is evidently a *solid* compact substance, and not a mere cloud or shining fluid; for it casts a deep shadow upon different regions of the planet, which is plainly perceived by good telescopes. Besides, were it not a solid arch, its centrifugal force, caused by its rapid rotation, would soon dissipate all its parts, and scatter them in the surrounding spaces. It is not yet ascertained whether both the rings have the same period of rotation. This magnificent appendage to the globe of Saturn is about 30,000 miles distant from the surface of the planet, so that four globes nearly as large as the earth could be interposed between them; it keeps always the same position with respect to the planet; is incessantly moving around it; and is carried along with the planet in its revolution round the sun.

The surface of the double ring does not seem to be exactly plane. One of the ansæ† sometimes disappears and presents its dark edge, while the other ansa continues to appear, and exhibits a part of its plane surface.

* Sir John Herschel states the dimensions of these rings on a somewhat lower scale than what his father determined. He says that they were calculated from Professor Struve's micrometrical measures; but admits that some of the dimensions he states are perhaps too small.

† The parts of the ring about the ends of the longest axis, reaching beyond the disk of the planet, are called the *ansæ*. Ansa signifies a *handle*, which name was given when telescopes were so imperfect as to represent Saturn as a globe with two small knobs on each side. The same name is still continued, though it is somewhat improper, now that the true shape of this appendage is known. Still the general appearance of Saturn is somewhat like a globe, with an ansa or handle on each side.

On the 9th of October, 1714, the ansæ appeared twice as short as usual, and the eastern one much longer than the western. On the first of the same month, the largest ansa was on the east side; on the 12th, the largest ansa was on the west side of Saturn's disk;* which led the observers, even at that period, to conclude that the ring had a rotation round the planet. On the 11th of January, 1774, M. Messier observed both the ansæ completely detached from the planet, and the eastern one larger than the other. In 1774, Sir W. Herschel likewise observed Saturn with a single ansa. From these observations, it has been concluded that there are irregularities on the surface of the ring, analogous, perhaps, to mountains and vales of vast extent; and that the occasional disappearance of the ansæ may possibly arise from a curvature in its surface. Sir W. Herschel was of opinion that the *edge* of the exterior ring is not flat, but of a spherical, or rather spheroidal form.

*Dimensions of Saturn's Rings.*—It is difficult for the mind to form an adequate conception of the magnitude, the mechanism, and the magnificence of these wonderful rings, which form one of the most astonishing objects that the universe displays. In order to appreciate, in some measure, the *immense size* of these rings, it may be proper to attend to the following statements: Suppose a person to travel round the outer edge of the exterior ring, and to continue his journey without intermission at the rate of twenty-five miles every day, it would require more than *seventy years* before he could finish his tour round this immense celestial arch. The interior boundary of the *inner* ring incloses a space which would be sufficient to contain within it three hundred and forty globes as large as the earth; and the *outer* ring could inclose within its inner circumference five hundred and seventy-five globes of the same magnitude, supposing every portion of the inclosed area to be filled. This outer ring would likewise inclose a globe containing 2,829,580,622,048,-315, or more than two thousand eight hundred *billions* of cubical miles, which globe would be equal to more than *ten thousand eight hundred globes* of the size of the earth. In regard to the *quantity of surface* contained in these rings, the one side of the outer ring contains an area of 4,529,401,800, or more than four thousand five hundred millions of square miles. The one side of the inner ring contains 9,895,780,818, or nearly ten thousand millions of square miles. The two rings, therefore, contain on one side above fourteen thousand four hundred millions of square miles; and as the other sides of the rings contain the same extent of surface, the whole area comprehended in these rings will amount to 28,850,365,236, or more than twenty-eight thousand eight hundred millions of square miles. This quantity of surface is equal to 146 times the number of square miles in the terraqueous globe, and is more than 588 times the area of all the habitable portions of the earth. Were we to suppose these rings inhabited (which is not at all improbable,) they could accommodate a population, according to the rate formerly stated, of 8,078,102,266,080, or more than *eight billions*, which is equal to more than *ten thousand times* the present population of our globe; so that these rings, in reference to the space they contain, may be considered, in one point of view, as equal to ten thousand worlds.

Were we to take into consideration the *thickness* of the rings, we should find a very considerable addition to the area above stated. Supposing, according to Sir J. Herschel's estimate, that they are only one hundred miles thick, the area of the exterior circumference of the edge of the *outer* ring will be 64,365,-700 miles; and that of the interior edge, 59,-777,100. The exterior edge of the *inner* ring will contain an area of 57,954,200 square miles, and the interior edge 45,980,000; in all, 228,077,000 square miles, which is thirty-one millions of square miles more than the whole area of our globe.

These rings, therefore, exhibit a striking idea of the *power* of the Creator, and of the grandeur and magnificence of his plans and operations. They likewise display the depths of his *wisdom* and intelligence; for they are so adjusted, both in respect to their position around the body of the planet and to the degree of motion impressed upon them, as to prevent both their falling in on the planet and their flying off from it through the distant regions of space. We have already stated that the rings are not exactly concentric with the body of the planet. Now, it is demonstrable, from physical considerations, that were they mathematically perfect in their circular form, and exactly concentric with the planet, "they would form a system in a state of *unstable equilibrium*, which the slightest external power," such as the attraction of the satellites, "might completely subvert, by precipitating them unbroken on the surface of the planet." For physical laws must be considered as operating in the system of Saturn as well as in the earth and moon, and the other planets; and every minute circumstance must be adjusted so as to correspond with these laws. "The observed oscillation," says Sir J. Herschel, "of the centres of the rings about that of the planet is, in itself, the evidence of a

* Memoirs of the Royal Academy of Sciences for 1715.

perpetual contest between conservative and destructive powers, both extremely feeble, but so antagonizing one another as to prevent the latter from ever acquiring an uncontrollable ascendency and rushing to a catastrophe." "The smallest difference of velocity between the body and rings must infallibly precipitate the latter on the former, never more to separate; consequently, either their motions in their common orbit round the sun must have been adjusted to each other by an external power with the minutest precision, or the rings must have been formed about the planet while subject to their common orbitual motion and under the full free influence of all the acting forces." Here, then, we have an evident proof of the consummate wisdom of the almighty Contriver in so nicely adjusting every thing in respect to number, weight, position, and motion, as to preserve in undeviating stability and permanency this wonderful system of Saturn; and we have palpable evidence that every thing conducive to this end has been accomplished, from the fact that no sensible deviation has been observed in this system for more than 220 years, or since the ring was discovered; nor, in all probability, has there ever been any change or catastrophe in this respect since the planet was first created and launched into the depths of space.

*Appearance of the Rings from the Body of Saturn.*—These rings will appear in the firmament of Saturn like large luminous arches or semicircles of light, stretching across the heavens from the eastern to the western horizon, occupying the one fourth or one fifth part of the visible sky. As they appear more brilliant than the body of the planet, it is probable that they are composed of substances fitted for reflecting the solar light with peculiar splendour, and therefore, will present a most magnificent and brilliant aspect in the firmament of Saturn. Their appearance will be different in different regions of the planet. At a little distance from the equator they will be seen nearly as complete semicircles, stretching along the whole celestial hemisphere, and appearing in their greatest splendour. In the daytime they will present a dim appearance, like a cloud or like our moon when the sun is above the horizon. After sunset their brightness will increase, as our moon increases in brilliancy as the sun disappears, and the shadow of the globe of Saturn will be seen on their eastern boundary directly opposite to the sun. This shadow will appear to move gradually along the rings till midnight, when it will be seen near the zenith, or the highest point of these celestial arches. After midnight it will appear to decline to the western horizon, where it will be seen near the time of the rising of the sun. After sunrise the brightness decays, and it appears like a cloudy arch throughout the day. The following circumstances will add to the interest of this astonishing spectacle: 1. The *rapid motion* of the rings, which will appear to move from the eastern horizon to the zenith in two hours and a half. 2. The *diversity of surface* which the rings will exhibit; for if we can trace inequalities upon these rings by the telescope at the distance of more than 800,000,000 of miles, much more must the inhabitants of Saturn perceive all the variety with which they are adorned when they are placed so near them as the one eighth part of the distance of our moon. Every two or three minutes, therefore, a new portion of the scenery of the rings will make its appearance in the horizon with all their diversified objects; and if these rings be inhabited, the various scenes and operations connected with their population might be distinguished from the surface of Saturn with such eyes as ours, aided by our most powerful telescopes. 3. The motion of the shadow of the globe of Saturn in a direction contrary to the motion of the rings, which shadow will occupy a space of many thousand miles upon the rings, will form another variety of scenery in the firmament. 4. If the two rings revolve around the planet in different periods of time, the appearance in the celestial vault will be still more diversified; then one scene will be seen rising on the upper, and another and a different scene rising on the lower ring; and, through the opening between the rings, the stars, the planets, and one or two of the satellites may sometimes appear.

Near the polar regions of the planet only a comparatively small portion of the rings will appear above the horizon, dividing the celestial hemisphere into two unequal parts, and presenting the same general appearance now described, but upon a smaller scale. Towards the polar points the rings will, in all probability, be quite invisible. During the space of fourteen years and nine months, which is half the year of this planet, the sun shines on the one side of these rings without intermission, and during the same period he shines on the other side. During nearly fifteen years, therefore, the inhabitants on one side of the equator will be enlightened by the sun in the daytime and the rings by night, while those on the other hemisphere, who live under the dark side of the ring, suffer a solar eclipse of fifteen years' continuance, during which they never see the sun. At the time when the sun ceases to shine on one side of the ring and is about to shine on the other, the rings will be invisible for a few days or weeks to all the inhabitants of Saturn.

At first view we might be apt to suppose that it must be a gloomy situation for those

who live under the shadow of the rings during so long a period as fifteen years; but we are not acquainted with *all the circumstances* of their situation, or the numerous beneficent contrivances which may tend to cheer them during this period, and, therefore, are not warranted to conclude that such a situation is physically uncomfortable. We know that they enjoy the light of their moons without almost any interruption; sometimes two, sometimes four, and sometimes all their seven moons are shining in their hemisphere in one bright assemblage. Besides, during this period is the principal opportunity they enjoy of contemplating the starry firmament, and surveying the more distant regions of the universe, in which they may enjoy a pleasure equal, if not superior, to what is felt amid the splendour of the solar rays; and it is not improbable that multitudes may resort to these darker regions for the purpose of making celestial observations; for the bright shining of the rings during the continuance of night will, in all probability, prevent the numerous objects in the starry heavens from being distinguished. The very circumstances, then, which might, at first view, convey to our minds images of gloom and horror, may be parts of a system in which are displayed the most striking evidences of beneficent contrivance and design. It must be a striking scene when the sun is of a sudden altogether intercepted, without any apparent cause, not to return for fifteen years; and, on the other hand, when, at the end of this period, his light again bursts all at once upon the astonished beholders, closing up, as it were, the prospects of the firmament, and diffusing his splendour on every surrounding object; and both events may be attended with sentiments of admiration and emotions of delight. At certain times of the year of Saturn, and in certain latitudes from his equator, the sun will be eclipsed for a short time, every day at noon, by the upper part of the exterior ring, according as he declines more or less to the opposite side; and sometimes he will be partially eclipsed by the under side of the exterior ring and the upper side of the interior, and sometimes will be seen moving along the interval which separates these rings.

The following figures are intended to convey a rude idea of the objects connected with the firmament of Saturn.

Fig. 59, represents the appearance of the rings at a little distance from the planet's equator, where they will appear nearly as complete semicircles. *A B* represents a portion of the globe of Saturn; *C D* the shadow of Saturn, as it appears upon the rings at midnight, after which it will appear to move gradually to the west till sunrise, when it will disappear below the horizon. The sun, partly eclipsed by the upper and lower edge of the rings in the daytime, is represented at *e*, *f*, *g*, and *h*. The other objects are some of the satellites in different phases, and the fixed stars, of which few will probably be seen, some of them within and some of them beyond the

Fig. 59.

Fig. 60.

rings. Fig. 60, represents the rings as they will appear from places near the polar regions of the planet, from which situations they will appear as only small segments of circles near the horizon. The nearer the pole, the smaller the circles will appear.

From the above description, it appears that there is a great *variety* in the scenery presented in the firmament of Saturn; and this scenery is different as viewed from different regions of the planet. From the regions near the equator the rings will appear to the greatest advantage and in all their splendour. From these positions the various objects connected with the rings will be most distinctly observed, as the spectators will be at the nearest distance from the inner ring, which is about thirty thousand miles. At the latitude of 45° they will be twenty thousand miles further from them; they will appear at a much lower elevation above the horizon, a smaller portion of their curve will be seen, and their *breadth* will occupy a less space in the heavens. At a higher latitude a still smaller portion will be seen, till they dwindle to a small curve or speck of light in the hori-

son; and at the poles they will be quite invisible by the interposition of the equatorial parts of the planet. Immediately under the equator the light of the rings will be scarcely visible, but the sun will occasionally illuminate the under edge of the interior ring, at *f, e, D*, and other places; which, at night, will appear like a narrow luminous arch stretching directly across the zenith from the eastern to the western horizon, and diversified with the motion of the shadow of Saturn. Besides the different appearances of the starry regions, the various aspects of the moons, some of them rising, setting, and culminating,* some of them appearing as crescents, half moons, and full enlightened hemispheres, some entering into an eclipse, and some emerging from it, and all of them appearing to move with a rapid velocity around the sky, will greatly add to the *variety* and diversity of scenery which appears in the firmament of this planet. This diversity of aspect, which the scenery of nature presents from different regions of the planet, will, in all probability, have a tendency to promote frequent intercourses among the different tribes of its inhabitants, in order to contemplate the different scenes of nature and providence displayed throughout this spacious and magnificent globe. All these circumstances, properly considered, form of themselves a presumptive argument to prove that the sublime and exquisite contrivances connected with this planet were not intended merely to illuminate barren sands and hideous desarts, but to afford a comfortable and magnificent habitation for thousands of millions of rational inhabitants, who employ their faculties in the contemplation of the wonders which surround them, and give to their Creator the glory which is due to his name.

It has often been asked as a mysterious question, "What is the *use* of the rings with which Saturn is environed?" This is a question which I conceive there is no great difficulty in answering. The following considerations will go a great way in determining this question: 1. They are intended to produce all the varieties of celestial and terrestial scenery which I have described above, and doubtless other varieties with which we are unacquainted; and this circumstance of itself, although we could devise no other reason, might be sufficient to warrant the Creator to deviate from his general arrangements in respect to the other planets. For *variety* is one characteristic of his plans and operations, both in respect to the objects on our globe and to those which exist throughout the planetary system, and it is accordant with those desires for novelty and variety which are implanted in the minds of intelligent beings. 2. They are intended to give a display of the *grandeur* of the Divine Being, and of the effects of his omnipotence. They are also intended to evince his inscrutable wisdom and intelligence in the nice adjustment of their motions and positions, so as to secure their stability and permanency in their revolutions, along with the planet, around the sun. 3. They are doubtless intended to teach us what varied scenes of sublimity and beauty the Deity has introduced or may yet introduce into various regions throughout the universe. We are acquainted with only a few particulars respectiong *one* planetary system; but we have every reason to conclude that many millions of similar or analogous systems exist throughout the unlimited regions of space. In some of those systems the arrangements connected with the worlds which compose them may be as different from those of our globe and some of the other planets, as the arrangements and apparatus connected with Saturn are different from those of the planet Vesta or Mars. Around some of these worlds there may be thrown not only two concentric rings, but rings standing at right angles to each other, and inclosing and revolving round each other; yea, for aught we know, there may be an indefinite number of rings around some worlds, and variously inclined to each other, so that the planet may appear like a terrestial globe suspended in the middle of an armillary sphere; and all those rings may be revolving within and around each other in various directions and in different periods of time, so as to produce a variety and sublimity of aspect of which we can form no adequate conception. There is nothing irrational or extravagant in these suppositions; for, had we never discovered the rings of Saturn, we could have formed no conception of such an appendage being thrown around any world, and it would have been considered in the highest degree improbable and romantic had any one broached the idea. We are therefore led to conclude, from the characteristic of *variety* impressed on the universe, that Saturn is not the only planet in creation that is surrounded with such an apparatus, and that the number and position of its rings are not the only models according to which the planetary arrangements in other systems may be constructed.

4. Besides the considerations now stated, the chief use, I presume, for which these rings were created was, *that they might serve as a spacious abode for myriads of intelligent creatures.* If we admit that the globe of Saturn was formed for the reception of rational inhabitants, there appears no reason why we should not also admit that the rings were con-

* A heavenly body is said to culminate when it comes to the meridian, or the highest point of its diurnal course.

structed chiefly for the same purpose. These rings, as we have already seen, contain a surface of about *thirty thousand millions* of square miles; and, if all the other planets be inhabited, it is not likely that the Creator would leave a space equal to nearly 600 times the habitable parts of our globe as a desolate waste, without any tribes of either sensitive or intelligent existence. It forms no objection to this idea that the rings are *flat*, and not globular like the planets; for the Creator can arrange any figure of a world into a suitable abode for intelligent beings; and on our globe we find myriads of animated beings fitted for every mode of existence, and in situations where we should scarcely ever have expected to see them. Besides, three or four centuries have scarcely elapsed since the earth was generally considered as a *plane* indefinitely extended; and the idea of its being a globe, inhabited on all sides, was scouted as untenable, and considered far more ridiculous than it can be now to suppose the flat rings of Saturn as serving the purpose of a habitable world. What should hinder them from serving this purpose as well as the globe of Saturn? They are *solid* arches, which is evident from their shadows and their rapid motion; they contain an ample space for an immense population; they have the power of attraction, like other material substances connected with the solar system; they are capable of being adorned with as great a diversity of surface, and as great a variety of beautiful and sublime objects, as this earth or any other of the planetary bodies; and it can make no great difference in the enjoyments of sentient and intellectual beings whether they live on a globe, a spheroid, a cylinder, or a plane surface, which the hand of Wisdom and Omnipotence has prepared for their reception; while it displays, at the same time, the variety of modes in which the Universal Parent can convey happiness to his numerous offspring. It may, perhaps, be objected to the idea of the habitability of these rings, that, while one side is enlightened during fifteen years without intermission, the other side remains in the dark during the same period. But the same thing happens to extensive regions on the globe of Saturn; and, doubtless, arrangements are made for the enjoyment of the inhabitants in both cases during this period. They enjoy in succession, and sometimes all at once, the light reflected from at least seven moons, and they behold occasionally the body of Saturn reflecting the solar rays from certain parts of its surface, and appearing like a vast luminous crescent, in different degrees of lustre, suspended in the sky. (See p. 88.)

Many other views and descriptions might be given of the phenomena connected with the system of Saturn, were it not that I do not wish to exhaust the patience of the reader by dwelling too long on one subject. The circumstance of two concentric rings being thrown around a planet, however simple it may at first sight appear, involves in it an immense variety of peculiar and striking phenomena, in regard both to the inhabitants of the planet and of the rings, so that it is difficult for the mind to form a precise and definite conception of every particular. To acquire even a general view of such phenomena, it would be requisite to construct a pretty large machine, representing the system of Saturn, in all its known motions and proportions, and to make it revolve around a central light. An instrument of this kind is as necessary for illustrating the subject on which we have been descanting, as an orrery or planetarium to illustrate the seasons and the planetary motions.

*Telescopic Views of Saturn and its Rings.*—As these rings present a variety of aspects as seen from different parts of the planet, so they appear to assume a different appearance at different times when viewed through our telescopes. Sometimes the planet appears to be completely divested of its rings; sometimes they appear only like a short luminous line or streak on each side of its body; sometimes they appear like handles on each side of the planet; and at other times like a large ellipse or oval almost surrounding the body of the planet. These varied aspects of the rings are owing to the following circumstances. The rings never stand at right angles to our line of vision; otherwise we should see them as represented in Fig. 58, (p. 84.) Our eye is never elevated more than thirty degrees above the plane of the rings. The *plane* of these rings preserves a position parallel to itself in every part of the planet's revolution, being constantly inclined at the same, or nearly the same angle to the orbit and to the ecliptic, which angle is about twenty-nine or thirty degrees. The *nodes of the rings* lie in 190° and 350° of longitude, which correspond to the twentieth degree of Virgo and the twentieth of Pisces. When, therefore, the planet is in these points, the rings entirely disappear, because the thin edge of the outer ring only is turned towards our eye, and every trace of it is lost for some time, except the shadow of it, which appears like a dark belt across the planet. This disappearance happens once every fifteen years, but frequently with different circumstances. Two disappearances and two reappearances may occur in the same year, but never more. When Saturn is in the longitude above stated, the plane of the rings passes through the sun, and, the light then falling upon it edgewise, it is to us no longer visible. The rings likewise

disappear when their plane passes through the earth; for its edge being then directed to the eye, and being too fine to be seen, the planet appears quite round and unaccompanied with its rings. When the earth is placed on the side of the rings which is turned from the sun, we have a third cause of its disappearance. As the planet passes from the ascending to the descending node of the rings, the *northern* side of their plane is turned towards the sun. As it passes from the descending to the ascending node, the *southern* side of the rings is enlightened. In proportion as it recedes from these nodes, the rings appear to widen and to present a broader ellipsis, till it arrives at 90° from either node, or in 80° or 260° of longitude, corresponding to 20° of Gemini and 20° of Scorpio; at which time the rings will be seen to the greatest advantage, and appear almost surrounding the globe of Saturn. At the time of the greatest opening of the rings, their shorter diameter appears exactly one half of the longer diameter.

The following figures represent the different appearances of the rings, during half the period of the revolution of Saturn, as seen through good telescopes. Fig. 60 shows the appearance of Saturn when the plane of the ring is parallel to the line of vision, and its thin edge turned to the eye. In this manner the planet appeared during the months of October, November, and part of December, 1832, when nothing was perceptible except the dark shade across its disk, as represented in the figure. The first time the weather permitted observations on Saturn about this period was December 27, when I perceived the ring, with a power of 180, appearing like a fine thread of light on each side of the planet, as represented Fig. 61. About the beginning of October the plane of the ring passed through the centre of the sun. At that time the inhabitants of Saturn, who had previously been in darkness, would perceive the margin of the sun projecting over the edge of the ring like a brilliant streak of light, and, in the course of about four of our days, or nine days of Saturn, the whole body of the sun would appear above the plane of the ring, gradually rising a little higher every day, as he does after the 21st March to the north pole of the earth. The ring began to appear a little larger during the months of January, February, and March, 1833; but in April it again disappeared, as the earth was then in the plane of the ring, and it continued invisible till near the end of June. After which it again appeared, as represented in Fig. 61, and will now continue visible till the year 1847, when it will again disappear. In about a year after its second disappearance, it appeared as in Fig. 62. In about a year and a half afterward the opening between the rings appeared wider, as in Fig. 63; and in 1837 it appeared as in Fig. 64. In Fig. 65 the rings are represented at the utmost extent in which they are ever seen, along with the dark space that separates the two rings, which can only be distinguished by a telescope magnifying from 220 to 300 times. In this position it will be seen in 1840; after which it will pass through all the gradations here represented, appearing narrower every year till 1847, when it will be seen as in Fig. 61; soon after which it will entirely disappear, and the planet will be seen as if divested of its ring, as represented in Fig. 60. Such are the various aspects under which Saturn and its rings appear, as viewed through powerful telescopes.

### IX. ON THE PLANET URANUS.

Since the time of Newton, when the physical causes of the celestial motions began to be studied and investigated, astronomers have had their attention directed to the power or influence which the planetary bodies exert upon each other. This power is termed attraction or gravitation, and is inherent in all material substances, so far as our knowledge extends. It is exerted in proportion to the quantity of matter and the distances of the respective bodies; the planets, in their nearest approach to each other, causing some slight deviations in their orbits and motions. Some

disturbances or inequalities in the motions of Jupiter and Saturn, which could not be accounted for from the mutual action of these planets, led certain astronomers to conclude that another planet of considerable magnitude existed beyond the orbit of Saturn, by the action of which these irregularities were produced. It was not, however, till near the close of the eighteenth century that this happy conjecture was realized and confirmed. To the late Sir W. Herschel astronomy is indebted for discovering a new primary planet, which had been previously unknown to all astronomers.

This illustrious astronomer, when residing in Bath, had constructed reflecting telescopes of a larger size and with higher powers than any that had been previously in use, and had devoted his unwearied attention to celestial observations. While pursuing a design which he had formed, of making minute observations on every region of the heavens, on the 13th of March, 1781, while examining, with one of his best telescopes, the constellation of Gemini, he observed a star near the foot of Castor, the light of which appeared to differ considerably from that of the neighbouring stars, or those which he found described in catalogues. On applying a higher magnifying power it appeared evidently to increase in diameter; and two days afterward he perceived that its place was changed, and that it had moved a little from its former position. From these circumstances he concluded that it was a comet, and sent an account of it as such to the astronomer royal. As a comet, however, it seemed particularly singular that no tail or nebulous appearance could be perceived; on the contrary, it was found to show with a faint steady light, somewhat paler than that of Jupiter. The account of this discovery soon spread throughout Europe, and was confirmed by observations made at Paris, Vienna, Milan, Pisa, Berlin, and Stockholm. The star was for some time generally considered as an extraordinary comet, free of all nebulosity, and astronomers were occupied in determining the parabolic elements of its course. "The President Bochard de Saron, of the Academy of Sciences of Paris, and Lexel, an astronomer of St. Petersburg, who was in London at the time, were the first who discovered its circular form, and calculated the dimensions of its orbit. It was no longer doubted that Herschel's star was a new planet; and all subsequent observations verified this unexpected result."* We have here a striking proof of the perfection of modern theories; for the laws regulating the motion of this new planet were determined before it had accomplished the twentieth part of its course, and that motion was not less accurately known than that of other planets which had been observed during so many centuries. Since its discovery to the present time, it has not yet moved much more than two-thirds of a revolution round the sun; and yet its motions are calculated, and its place in the heavens predicted, with as much accuracy and certainty as those of the other planets, a circumstance which demonstrates the precision of modern astronomers, and which should lead the unskilful in astronomy to rely on the deductions of this science, however far they may transcend their previous conceptions.

When the motion of this new planet was calculated, the points of the heavens which it successively occupied during the preceding century could be pointed out; and it occurred to some astronomers that it might possibly have been observed before, though not known to be a planet. Mr. Bode, of Berlin, who had just published a work containing all the catalogues of zodiacal stars which had appeared, was induced to consult these catalogues in order to discover whether any star marked by one astronomer, and omitted by another, might not be the new planet in question. In the course of this inquiry he found that the star No. 964 in Mayer's catalogue had been unobserved by others, and observed only once by Mayer himself, so that no motion could have been perceived by him. On this Mr. Bode immediately directed his telescope to that part of the heavens where he might expect to find it, but without success. At the same time he found, by calculation, that its apparent place in the year 1756 ought to have been that of Mayer's star, and this was one of the years in which he was busied in his observations; and, on further inquiry, it was found that the star 964 had been discovered by Mayer on the 15th of September, 1756; so that it is now believed that this star was the new planet of Herschel. It appears likewise that this star was seen several times by Flamstead, the astronomer royal, in the year 1690; once by Bradley; and eleven times by Lemonnier; all of whom considered it as one of the fixed stars, but never suspected that it was a planetary body. The discovery of this planet enlarges our views of the extent of the solar system, and of the quantity of matter it contains, far more than if planets equal to Mercury, Venus, the Earth, the Moon, Mars, Vesta, Juno, Ceres, and Pallas, were to be added to that system; for, although it is scarcely distinguishable by the naked eye on the vault of heaven, it is more than twenty times larger than all these bodies taken together.

* Biographical Memoir of Sir W. Herschel, by Baron Fourier. Read to the Royal Academy of Sciences, June 7, 1824.

After this body was ascertained to belong to the planetary system, it became a subject of consideration by what name it should be distinguished. The old planets were distinguished by names borrowed from the heathen deities, a nomenclature which, perhaps, it might now be expedient to change; but Galileo and Cassini gave to the celestial bodies they discovered the names of the princes who had patronized their labours. Hence Galileo, when he had discovered the satellites of Jupiter, sent his drawings of them to his patron, Cosmo Medici, Great Duke of Tuscany, in honour of whom he called them *Medicean stars;* and Cassini named the satellites of Saturn which he discovered after Louis XIV. In imitation of these discoveries, Sir W. Herschel named his newly-discovered planet *Georgium Sidus*, in honour of his patron George the Third. But foreign astronomers, for a considerable time, gave it the name of *Herschel*, in honour of the discoverer; but afterwards hesitated between the names Cybele, Neptune, and *Uranus*. This last name, derived from one of the Nine Muses who presided over astronomy, ultimately prevailed, and will probably distinguish this planet in future generations, unless the present nomenclature of the planets be abolished.

*Distance and Period of Uranus.*—Uranus is the most distant planet of the solar system, so far as our knowledge yet extends; although it is by no means improbable that planets may exist even beyond its orbit, distant as it is; for comets pass far beyond the limits of this planet, and again return to the vicinity of the sun. Its distance from the sun, in round numbers, is 1,800,000,000; that is, eighteen hundred millions of miles, which is double the distance of the planet Saturn. When nearest the earth, it is distant from us about 1,705,000,000 of miles. In order to acquire a rude conception of this distance, let us suppose a steam-carriage to set out from the earth, and to move, without intermission, twenty miles every hour, it would require more than nine thousand, seven hundred and thirty years before it could reach the planet Uranus; so that, although the journey had been commenced at the creation of our globe, it would still require more than three thousand seven hundred years to arrive at its termination. Even a cannon ball, flying at the rate of twelve thousand miles every day, would require three hundred and eighty-nine years to reach the nearest point of the orbit of this planet. Yet the comet which appeared in 1835, in all probability, pursues its course far beyond the orbit of Uranus, and will, doubtless, visit this part of our system again, as it has done before, within the space of seventy-six years, although it must move more than double the above distance before it returns. The *circumference* of the orbit in which Uranus revolves about the sun is 11,314,000,000 of miles, through which it moves in 30,686 mean solar days, or about eighty-four years. It is the slowest moving planet in the system, and yet it pursues its course at the rate of 15,000 miles every hour. Were a steam-carriage to move round the immense orbit of this planet at the rate above stated, it would require no less than sixty-four thousand, five hundred and seventy years before this ample circuit could be completed; and yet a globe eighty times larger than the earth finishes this vast tour in eighty-four years! This planet doubtless revolves round its axis as the other planets do, but the period of its rotation is as yet unknown. Its great distance from the earth prevents us from observing any spots or changes on its surface by which its rotation might be determined. La Place concludes, from physical considerations, that it revolves about an axis very little inclined to the ecliptic; and that the time of its diurnal rotation cannot be much less than that of Jupiter or Saturn.

*Magnitude and Dimensions of Uranus.*—This planet is about 35,000 miles in diameter, and 110,000 miles in circumference, being about eighty-one times larger than the earth, and four thousand times larger than the moon. Its surface contains 3,848,460,000 of square miles, which is nineteen times the area of our globe, and seventy-eight times the area of all the habitable portions of the earth. At the rate of population formerly stated, 280 to a square mile, it could, therefore, accommodate 1,077,568,800,000, or more than one billion of inhabitants, which is one thousand three hundred and forty-seven times the population of our globe. So that this planet, which escaped the notice of astronomers for more than five thousand years, forms a very considerable portion of the solar system and of the scene of the Divine government.

*Proportion of Light on Uranus.*—As this planet is nineteen times further from the sun than the earth is, and as the square of 19 is 361, the intensity of light on its surface will be three hundred and sixty times *less* than what we enjoy. Yet this quantity of light is equal to what we should have from the combined effulgence of three hundred and forty-eight full moons; and, with a slight modification of our visual organs, such a proportion of light would be quite sufficient for all the purposes of vision. Though the light of the sun flies eighteen hundred millions of miles before it reaches this planet, and returns again by reflection nearly the same distance before it reaches the earth, yet it is distinctly visible through our telescopes, and sometimes even to

the naked eye; and Uranus, with a moderate magnifying power, *appears* about as bright as Saturn. How small a quantity of solar light may suffice for the purpose of vision will be obvious by attending to the following circumstance: In the late solar eclipse which happened on the 15th of May, 1836, little more than the one twelfth part of the sun was visible at those places where the eclipse was annular. Almost every person imagined that a dismal gloom and darkness would ensue, yet the diminution of light appeared no greater than what frequently happens in a cloudy day. At the time of the greatest obscuration there was more than half the light which falls upon Uranus, and all the objects of the surrounding landscape, though somewhat deficient in brilliancy, were distinctly perceived. There can be no doubt that the organs of vision of the inhabitants of the different planets, being formed by Divine wisdom, are exactly adapted to the objects amid which they are placed, and the quantity of light reflected from them; and there may be innumerable modes, unknown to us, by which this end may be affected. We can easily conceive, that if the pupils of our eyes were rendered capable of a greater degree of expansion than they now possess, or were the *retina*, on which the images of objects are depicted, endowed with a greater degree of nervous sensibility, so as to be more easily affected by the impulses of light, we might perceive as much splendour on all the objects connected with Uranus, were we placed on that planet, as we now do on the scenery around us during the brightest days of summer. When we pass from the light of the sun into a darksome apartment, on our first entrance we can scarcely distinguish any objects with distinctness; but after remaining five or six minutes, till the pupil has time to expand, every object around us is readily perceived; and, from the same cause, nocturnal animals can pursue their course with ease and certainty amid the deepest shades of night; so that the inhabitants of the most distant planet of our system, although it were removed from the sun to double the distance of Uranus, might perceive objects with all the distinctness requisite for the purposes of vision; and if the pupils of the eyes of such beings be much more expansive than ours (as is probably the case,) it is highly probable they will be enabled to penetrate much further into the celestial regions, and to perceive the objects in the firmament with much greater distinctness and "space-penetrating power" than we can do, even with the aid of instruments. It is likewise probable that the objects on the surface of the more distant planets of our system are fitted to reflect the rays of light with peculiar brilliancy. Hence we find that the light of Uranus, though descending upon us from a region 900 millions of miles further than Saturn, appears as vivid as the light which is reflected to us from that planet. The apparent diameter of the sun, as seen from Uranus, is only 1 minute, 38 seconds; whereas his mean apparent diameter as seen from the earth is 32 minutes, 3 seconds; consequently this orb, as viewed from this planet, will appear very little larger than Venus appears to us in her greatest brilliancy, or Jupiter when near his opposition. The following figure represents to the eye the apparent size of the sun as seen from Uranus and from the earth, the small circle representing his size as seen from Uranus.

Fig. 66.

*Temperature of Uranus.*—If heat followed the same law as the propagation of light, and decreased as the square of the distance of the planet from the sun increased, then the surface of the planet Uranus would be a cold region indeed, in which no life or animation, such as we see around us, could exist. Baron Fourier, in his "Memoir of Herschel," says, "Its temperature is more than forty degrees below that of ice;" and if the degrees of Reaumur's thermometer be meant, this temperature will correspond to one hundred and twenty-two degrees below the freezing point of Fahrenheit; a cold enough region, truly. In accordance with such representations, the poets of the last century expatiated on the cold temperature of *Saturn* in such strains as the following:

"When the keen north with all its fury blows,
Congeals the floods, and forms the fleecy snows,
'Tis heat intense to what can there be known;
Warmer our poles than is its burning zone.
Who there inhabit must have other powers,
Juices, and veins, and sense, and life, than ours.
One moment's cold, like theirs, would pierce the bone,
Freeze the heart's blood, and turn us all to stone."
BAKER'S *Universe*.

This, it must be admitted, is *a very cold* poetic strain, almost sufficient to make one shiver, and to freeze our very thoughts; and if such a description were applicable to Sa-

turn, it is much more so to the planet Uranus, at double the distance. But I presume it is more in accordance with poetic license than with the deductions of sound philosophy. We have no valid reason to conclude that the degree of heat on the surfaces of the different planets is inversely proportional to the squares of their respective distances from the sun. The sun is to be considered chiefly as the great storehouse of *light*, and it may likewise be viewed as the great agent in the production of heat, without supposing it to be an enormous mass of fire, which the common opinion seems to take for granted. Its rays produce heat chiefly by exciting an insensible action between *caloric* and the particles of matter contained in bodies; and caloric appears to be a substance universally diffused throughout nature. If the degree of heat were in proportion to the distance from the sun, why should the upper regions of the atmosphere be so intensely cold? Why should the tops of lofty mountains be crowned with perpetual snows, while the plains below are scorched with heat? Why should an intense cold be felt in the latitude of 40°, when a comparative mildness is experienced in the latitude of 56°? In the state of Connecticut, North America, in January, 1835, the thermometer ranged from *minus* 25° to 27° of Fahrenheit; while in Scotland, during the same period, it was seldom so low as the freezing point. But as I have already thrown out some remarks on this subject when describing the planet Mercury, I need not enlarge (see page 34.) In order to form correct ideas of the distribution of heat among the planetary bodies, we have only to suppose that the Creator has proportioned the quantity of caloric (or that which produces sensible heat) to the distance at which every planet is placed from the sun, so that a large quantity exists in Saturn and a smaller quantity in Mercury. If, therefore, the quantity of caloric connected with Uranus be in proportion to its distance from the sun, there may be as much warmth experienced in that distant region of the solar system as in the mildest parts of our temperate zones. So that we are under no necessity of associating the frigid and gloomy ideas of the poet with our contemplations of this expansive globe. At all events, we may rest assured that the Creator, whose wisdom is infinite in its resources, and whose "tender mercies are over all his works," has adapted the structure and constitution of the inhabitants of every planet to the nature and circumstances of the habitation provided for them, so as to render every portion of his dominions a comfortable abode for his intelligent offspring; provided they do not frustrate his benevolent designs (as has been done in our world) by their rebellion and immoral conduct. For in no region of the universe, whatever may be its physical arrangements, can true happiness be enjoyed, unless love to God and love to all surrounding intelligences form the grand principles of action, and be uniformly displayed in every intercourse and association, and amid all the ramifications of moral conduct. On this basis chiefly rests the happiness of the intelligent universe; and, wherever principles directly opposite to these prevail among any order of intellectual beings, whatever may be the structure or scenery of their habitation, misery and moral disorder must be the inevitable consequence.

The following additional particulars may be stated in relation to this planet: Its *density* is reckoned to be nearly equal to that of water. A body weighing one pound on the earth's surface would weigh only fourteen ounces, fourteen drachms, if removed to Uranus. The *eccentricity* of its orbit is 85,000,000 of miles, which is about the 1-42 part of its diameter. Its mean *apparent diameter*, as seen from the earth, is about four seconds. The *inclination of its orbit* to the ecliptic is forty-six minutes, twenty-six seconds, so that it is never much more than three-fourths of a degree from the ecliptic. This inclination is less than that of any of the other planetary orbits. Six satellites are supposed to be connected with Uranus, but their periods and other phenomena have not yet been accurately ascertained.

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In the preceding pages I have given a brief sketch of the principal phenomena connected with the *primary* planets of our system. Whether any other planets besides those specified belong to this system is at present unknown. We have no reason to believe that the boundaries of the planetary system are circumscribed within the range of our discoveries or the limits of our vision. Within the space of little more than half a century, the limits of this system have been expanded to our view to double the extent which they were formerly supposed to comprehend. Instead of an area of only 25,400,000,000 of square miles, it is now found to comprise an extent of 101,700,000,000 of square miles, which is four times the dimensions formerly assigned to it. There would be no improbability in conceiving it extended to at least triple these dimensions. Within the space of twenty-six years, from 1781 to 1807, no fewer than five primary planets and eight secondaries were discovered, besides a far greater number of comets than had ever before been detected within a similar lapse of years; and therefore it would be obviously

rash and premature to conclude that we have now discovered all the moving bodies of our system. Far beyond the limits of even Uranus other planets yet unknown may be performing their more ample circuits around the sun; for we know, from the case of comets, that even throughout those distant regions his attractive power and influence extend. In the immense interval of 900,000,000 of miles between the orbits of Saturn and Uranus, one, if not two planets may possibly exist, though they have hitherto eluded the observation of astronomers. In order to detect such bodies, if any exist, it would be requisite to survey, more minutely than has yet been done, a zone of the heavens extending at least twenty degrees on each side of the ecliptic, marking exactly the minutest objects in every part of it which the most powerful telescopes can enable us to descry. After which a second survey should be made to ascertain if any of the bodies formerly observed be found amissing or have shifted their position. It might likewise be expedient to compare with new observations the stars marked in all the celestial atlases that have hitherto been published, and to note particularly those which are wanting where they were formerly marked, and those that have appeared in certain places where they were formerly unobserved. If a taste for celestial investigations were more common among mankind, and were the number of observers indefinitely increased, there would be no great difficulty in accomplishing such an object; for certain small portions of the heavens might be allotted to different classes of observers, who might proceed simultaneously in their researches, and in a comparatively short period the whole survey might be completed.

It is not improbable that a planet may exist within the space of 37 millions of miles which intervenes between the orbit of Mercury and the sun. But such a body could never be detected in the evening after sunset, as its greatest elongation from the sun could not be supposed to be more than ten or twelve degrees, and, consequently, it would descend below the horizon in about half an hour after sunset, and before twilight had disappeared. The only chance of detecting such a planet would be when it happened to transit the sun's disk; but as this would happen only at distant intervals, and as it might make the transit in cloudy weather, or when the sun is absent from our hemisphere, there is little prospect of our discovering such a body in this way. It might be of some importance, however, that those who make frequent observations on the sun should direct their attention to this circumstance; as there have been some instances in which dark bodies have been observed to move across the sun's disk in the space of five or six hours, when no other spots were visible. An opaque body of this description was seen by Mr. Lloft and others on the 6th of January, 1818, which moved with greater rapidity across the solar disk than Venus in her transit in 1769. It is possible that a planet within the orbit of Mercury might be detected in the daytime, were powerful telescopes applied to a space of the heavens about ten or twelve degrees around the sun. Small stars have been seen even at noonday with powerful instruments, and, consequently, a planet even smaller than Mercury might be perceived in the daytime. In this case, a round opaque body would require to be placed at a considerable distance from the observer, so as completely to intercept the body of the sun, and about a degree of the heavens all around him; and every portion of the surrounding space, extending to at least twelve degrees in every direction, should then be carefully and frequently examined. Such observations, if persevered in, would undoubtedly afford a chance of detecting any revolving body that might exist within such a limit. But I may afterward have an opportunity of describing more particularly the observations, and the mode of conducting them, to which I allude.



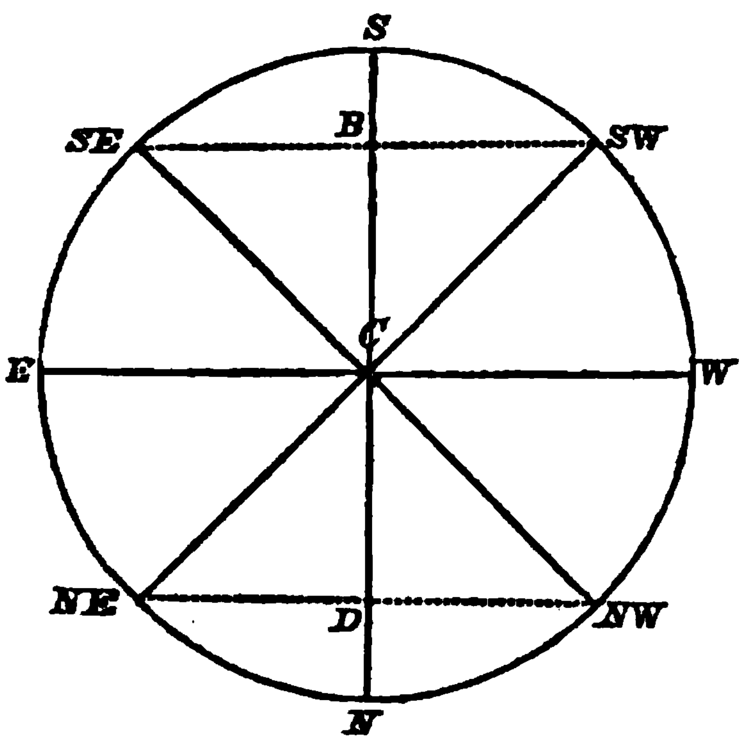
## X. THE SUN.

Having taken a cursory survey of the most prominent particulars connected with the primary planets, I shall now proceed to a brief description of the *sun*, that magnificent luminary on which they all depend, from which they derive light, and heat, and vivifying influence, and by whose attractive energy they are directed in their motions and retained in their orbits. Before proceeding to a description of the particular phenomena connected with the sun, it may be expedient briefly to describe some of his *apparent* motions.

*Apparent Motions of the Sun.*—The most obvious apparent motion of the sun, which is known to every one, is, that he appears to rise in the morning in an easterly direction to traverse a certain portion of the sky, and then to disappear in the evening in a direction towards the west. Were we to commence our observations on the 21st of December, in the latitude of 52° north, which nearly corresponds to that of London, we should see the sun rising near the southeast point of the horizon, as at *S E*, Fig. 67, describing a comparatively small curve above the horizon, from *S E* to *S W*, in the southern quarter of the heavens, and setting at *S W*, near the southwest. At this season the sun remains only between seven and eight hours above the

horizon; and when he arrives at *S*, at midday, which is the highest point of his elevation, he is only about fourteen degrees above the horizon, which may be represented by the line *S B*. After disappearing in our horizon in the evening, he describes the large curve from *S W* to *W*, *N*, and *E*, till he again arrives in the morning near the point *S E*. All this curve is described *below* our horizon, and, therefore, the nights at this season are much longer than the days. After this period the sun rises every day at points a little further to the north, between *S E* and *E*, and sets in corresponding points in the west, between *S W* and *W*, till the 21st of March, when he rises at the point *E*, due east, and sets due west at the point *W*. At this time he moves through the semicircle *E*, *S*, *W*, and at noon he rises to the elevation of thirty-eight degrees above the southern horizon, which may be represented by the line *S C*. This is the period of the vernal equinox, when there is equal day and night throughout every part of the earth, the sun being twelve hours above and twelve hours below the horizon. After this period the sun rises to the north of the easterly point, and sets to the north of the westerly, and the length of the day rapidly advances till the 21st of June, when he rises near the north-east point, *N E*, and sets near the north-west point, *N W*, describing the large curve from *N E* to *E S W*, and *N W*. This period of the year is called the summer *solstice*, when the days are longest, at which time the sun rises at noon to an elevation of 61½ degrees above the horizon, which may be represented by the line *S D*, and he continues above the horizon for nearly seventeen hours. The length of the nights at this time is exactly the same as the length of the days on the 21st of December. The sun's nocturnal arch, or the curve he describes below the horizon, is that which is represented in the lower part of the figure from *N W* to *N E*. In more southern latitudes than fifty-two degrees, the sun rises to a higher elevation at noon; and in higher latitudes his meridian altitude is less than what is stated above. From the time of the summer solstice the days gradually shorten; the sun rises in a more southerly direction till the 23d of September, which is called the *autumnal equinox*, when he again rises in the eastern point of the compass, and every succeeding day at a point still farther to the south, till, on the 21st of December, or the *winter solstice*, he is again seen to rise near the south-east, and afterward to pass through all the apparent variations of motion above described.

Fig. 67.




Were we residing in southern latitudes, such as those of Buenos Ayres, the Cape of Good Hope, or Van Diemen's Land, the apparent motions of the sun would be somewhat different. Instead of beholding the sun moving along the *southern* part of the sky from the left hand to the right, we should see him direct his course along the northern part of the heavens from the right hand to the left. In other respects his apparent motions would nearly correspond to those above described. Were we placed in countries under the equator at the time of the equinoxes, the sun at midday would shine directly from the zenith, at which time objects would have no shadows. At all other times the sun is either in the northern or the southern quarter of the heavens. During the one half of the year he shines from the north, and the shadows of objects fall to the south; during the other half he shines from the south, and the shadows of all objects are projected towards the north. This is a circumstance which can never occur in our climate or in any part of the temperate zones. At the equator, too, the days and nights are of the same length, twelve hours each, throughout the whole year. Were we placed at the *poles*, the motion of the sun would present a different aspect from any of those we have described. At the north pole, on the 21st of March, we should see a portion of the sun's disk appear in the horizon after a long night of six months. This portion of the sun would appear to move quite round the horizon every twenty-four hours; it would gradually rise higher and higher till the whole body of the sun made its appearance. As the season advanced, the sun would appear to rise higher and higher till he attained the altitude of 23½ degrees above the horizon, which would take place on the 21st of June; after which his altitude would gradually decline till the 23d of September, when he would again appear in the horizon. During the whole of this period of six months there

is perpetual day, the stars are never seen, and the sun appears to go quite round the heavens every twenty-four hours without setting, in circles nearly parallel to the horizon. After the 23d of September the sun disappears, and a night of six months succeeds, which is occasionally enlivened by the moon, the stars, and the corruscations of the *aurora borealis*, during which period the south pole enjoys all the splendour of an uninterrupted day. In all places within the polar circles, the length of the longest day varies from twenty-four hours to six months. In the northern parts of Lapland, for example, the longest day is about six weeks; during this time the sun appears to move round the heavens without setting; but at noon, when he comes to the meridian, he is about 40 degrees above the *southern* horizon, and twelve hours afterward he appears elevated about six degrees above the *northern* horizon, from which point he again ascends till he arrives at the southern meridian.

Such are the apparent *diurnal* motions and general aspects of the sun in different parts of the earth, which are owing partly to the inclination of the axis of the earth to the plane of the ecliptic, and partly to the different positions in which a spectator is placed in different zones of the globe. It is almost needless to remark, that these motions of the sun are not *real*, but only *apparent*. While presenting all these varieties of motion, he is still a quiescent body in the centre of the planetary system. By the rotation of the earth round its axis, from west to east, every twenty-four hours, all these apparent motions of the sun are produced. This we have already endeavoured to prove in chap. i. p. 17–19.

Besides the apparent diurnal motion now described, there is another apparent motion of the sun in a contrary direction, which is not so much observed, and that is, his apparent motion from *west* to *east* through the whole circle of the heavens, which he accomplishes in the course of a year. This motion manifests itself by the appearance of the heavens during the night. The stars which lie near the path of the sun, and which set a little time after him, are soon lost in his light, and after a short time reappear in the east a little before his rising. This proves that the sun advances towards them in a direction contrary to his diurnal motion; and hence we behold a different set of stars in our nocturnal sky in summer and in winter. This apparent revolution of the sun is produced by the *annual* motion of the earth round the sun, of which I have already given an explanation (chap. i. p. 19,) along with certain demonstrative proofs that the sun is the centre of the planetary system, (see also chap. ii. p. 26–31.)

*Distance and Magnitude of the Sun.*—To find the exact distance of the sun from the earth is an object which has much interested and engaged astronomers for a century past. The angle of parallax being so small as about eight and a half seconds, rendered it for some time difficult to arrive at an accurate determination on this point, till the transits of Venus in 1761 and 1769. From the calculations founded upon the observations made on these transits, it has been deduced that the distance of the sun is about 95,000,000 of miles. This distance is considered by La Place and other astronomers to be within the 1-87 part of the true distance, so that it cannot be much below 94 millions on the one hand, nor much above 96 millions on the other. Small as this interval may appear when compared with the vast distances of some of the other celestial bodies, it is, in reality, a most amazing distance when compared with the spaces which intervene between terrestial objects; a distance which the mind cannot appreciate without a laborious effort. It is thirty-one thousand six hundred times the space which intervenes between Britain and America; and were a carriage to move along this space at the rate of 480 miles every day, it would require 542 years before the journey could be accomplished.

The *magnitude* of this vast luminary is an object which overpowers the imagination. Its diameter is 880,000 miles; its circumference, 2,764,600 miles; its surface contains 2,432, 800,000,000 of square miles, which is twelve thousand three hundred and fifty-times the area of the terraqueous globe, and nearly fifty thousand times the extent of all the habitable parts of the earth. Its solid contents comprehend 356,818,739,200,000,000,* or more than three hundred and fifty-six thousand billions of cubical miles. Were its centre placed over the earth, it would fill the whole orbit of the moon, and reach 200,000 miles beyond it on every hand. Were a person to travel along the surface of the sun, so as to pass along every square mile on its surface, at the rate of thirty miles every day, it would require more than two hundred and twenty millions of years before the survey of this vast globe could be completed. It would contain within its circumference more than thirteen hundred thousand globes as large as the earth, and a thousand globes of the size of Jupiter, which is the largest planet of the system. It is more than five hundred times larger than all the planets, satellites, and comets belonging to our system, vast and extensive as some of them are. Although its density is

* In some editions of the "Christian Philosopher," under the article *Astronomy*, this number is inaccurately stated; and the number which follows, *two thousand millions*, should be *two hundred millions*.

little more than that of water, it would weigh 3360 planets such as Saturn, 1067 planets such as Jupiter, 329,000 globes such as the earth, and more than *two millions* of globes such as Mercury, although its density is nearly equal to that of lead. Were we to conceive of its surface being peopled with inhabitants at the rate formerly stated, it would contain 681,184,000,000,000, or more than six hundred and eighty billions, which would be equal to the inhabitants of *eight hundred and fifty thousand worlds* such as ours.

Of a globe so vast in its dimensions, the human mind, with all its efforts, can form no adequate conception. If it is impossible for the mind to take in the whole range of the terraqueous globe, and to form a comprehensive idea of its amplitude and its innumerable objects, how can we ever form a conception, approaching to the reality, of a body one million three hundred thousand times greater? We may express its dimensions in figures or in words, but in the present state of our limited powers we can form no mental image or representation of an object so stupendous and sublime. Chained down to our terrestrial mansion, we are deprived of a sufficient range of prospect, so as to form a substratum to our thoughts, when we attempt to form conceptions of such amazing magnitudes. The imagination is overpowered and bewildered in its boldest efforts, and drops its wings before it has realized the ten thousandth part of the idea which it attempted to grasp. It is not improbable that the largest ideas we have yet acquired or can represent to our minds of the immensity of the universe are inferior to a *full and comprehensive idea* of the vast globe of the sun in all its connexions and dimensions; and, therefore, not only must the powers of the human mind be invigorated and expanded, but also the limits of our intellectual and corporeal vision must be indefinitely extended, before we can grasp the objects of overpowering grandeur which exist within the range of creation, and take an enlightened and comprehensive view of the great Creator's empire. And as such endowments cannot be attained in the present state, this very circumstance forms a presumptive argument that man is destined to an immortal existence, where his faculties will be enlarged and the boundaries of his vision extended, so as to enable him to take a large and comprehensive view of the wonders of the universe, and the range of the Divine government. In the mean time, however, it may be useful to allow our thoughts to expatiate on such objects, and to endeavour to form as comprehensive an idea as possible of such a stupendous luminary as the sun, in order to assist us in forming conceptions of objects still more grand and magnificent; for the sun which enlightens our day is but one out of countless millions of similar globes dispersed throughout creation, some of which may far excel it in magnitude and glory.

*Rotation of the Sun.*—This luminary, although it is placed in the centre of the system, in the enjoyment of perpetual day, and stands in no need of light from any other orb, yet is found to have a rotation round its axis. This circumstance seems to indicate that motion is essential to all the bodies of the universe, whether revolving in orbits around another body, or acting as the centres of light and attractive influence. And from what we know of the more distant bodies in the heavens, we have reason to believe that there is none of them in a state of absolute quiescence, but that they are all in incessant motion, either round their axes or around a distant centre. The rotation of the sun was discovered by the motion of certain dark spots across its disk. These spots appear to enter the disk on the east side, to move from thence with a velocity continually increasing till they arrive at the middle of the disk; they then move slower and slower till they go off at the sun's western limb; after which they disappear for about the same space of time they occupied in crossing the disk, and then enter again on the eastern limb and move onward in the same track as before, unless they suffer a change, as frequently happens, after they disappear from the western limb. The apparent *inequality* in the motion of the spots is purely optical, and is owing to the oblique view we have of the parts of a globe which are near the margin; but the motion is such as demonstrates that the spots are carried round with a uniform and equable motion. From the motion of these spots we learn, 1. That the sun is a globe, and not a flat surface; 2. That it has a rotation round its own axis; and, 3. That this rotation is performed in the same direction as the rotation of the planets and their annual revolutions, namely, according to the order of the signs of the zodiac. The time which a spot takes in moving from the eastern to the western limb is thirteen days and nearly sixteen hours, and, consequently, the whole apparent revolution is twenty-seven days and nearly eight hours. But this is not the true period of the sun's rotation; for as the earth has, during this time, advanced in its orbit from east to west, and in some measure followed the motion of the spot, the real time in which the spots perform their revolutions is found, by calculation,* to be twenty-five days, ten hours. Every part of the sun's equator, therefore, moves at the rate of 4532 miles every hour. The axis of the sun,

* The following is the proportion by which the true rotation is found: 365*d* 5*h*. 48*m*. + 27*d*. 7*h*. 37*m*.; or, 392*d*. 13*h*. 25*m*.: 365*d*. 5*h*. 48*m*.: : 27*d*. 7*h*. 37*m*.: 25*d*. 9*h*. 56*m*. = the true time of the sun's rotation.

round which this revolution is performed, is inclined 7 degrees 20 minutes to the ecliptic.

*The Solar Spots, and the Physical Construction of the Sun.*—Although the sun is the fountain of light, and is incessantly pouring a flood of radiance over surrounding worlds, yet the nature of this vast luminary, and the operations which are going on upon its surface and adjacent regions, are in a great measure involved in darkness. Before stating any opinions on this subject, it may be proper, in the first place, to give a brief description of the phenomena which have been observed on the surface of the sun. The first and most striking phenomenon is the dark spots to which we have alluded. These spots are of all sizes, from one twenty-fifth part of the sun's diameter to the one five hundreth part and under. The larger spots are uniformly dark in the centre, and surrounded with a kind of border or fainter shade, called a *penumbra.* This penumbra, which sometimes occupies a considerable space around the dark nucleus, is frequently of a shape nearly corresponding to that of the black spot. Sometimes two or more dark spots, and a number of small ones are included within the same *penumbra,* and at other times a number of small spots in a train, forming a kind of tail, accompany the larger ones. The *number* of the spots is very various; sometimes there are only two or three, sometimes above a hundred, and sometimes none at all. *Scheiner*, who was among the first that observed these spots, remarks, that "from the year 1611 to 1629 he never found the sun quite clear of spots, except a few days in December, 1624; at other times he was able to count twenty, thirty, and even fifty spots upon the sun at a time." Afterward, during an interval of twenty years, from 1650 to 1670, it is said that scarcely any were to be seen. But, since the beginning of last century, no year has passed, so far as we know, in which spots have not been seen. I have had an opportunity of viewing the sun with good telescopes several hundreds of times, but have seldom seen his surface altogether free of spots. In some years, however, they have been far more numerous than in others. In the beginning of 1835 comparatively few were seen, but during the latter part of it, the whole of 1836, and up to the present time (September, 1837,) they have been exceedingly numerous. On the 16th of November, 1835, with an achromatic telescope, magnifying about a hundred times, I perceived about ten different clusters; and, within the limits of two of the clusters, sixty different spots were counted, and in the whole of the other clusters above sixty more; making in all about 120 spots, great and small. On the 19th of October, 1836, and the 21st of February, 1837, I counted about 130; and on a late occasion I perceived spots of all descriptions to the amount of about 150. Such a number of spots are generally arranged into ten or twelve different clusters, each cluster having one or two large spots, surrounded with a number of smaller ones. Fig. 68, represents the spots of the sun nearly as they appeared on the 19th of October, 1836, some of the smaller spots being omitted. The larger spots are represented on a somewhat larger scale than they should be in proportion to the diameter of the circle; but they present nearly the same relative aspect they exhibited when viewed through the telescope at the time specified. Fig. 69 shows the large spot on a larger scale; and Fig. 70 a large spot which appeared in a subsequent observation, which had a bright streak or two in the centre.



The magnitude of some of the solar spots is astonishing. One of the spots seen November 16, 1835, was found to measure about the *fortieth part* of the sun's diameter; and as that diameter is equal to 880,000 miles, the diameter of the spot must have been 22,000 miles, which is nearly three times the diameter of the earth; and if we suppose it only a flat surface, and nearly circular, it contained 380,133,600 square miles, which is nearly double the area of our globe. The largest of the spots in the figure, including the penumbra, measured about the one twenty-first part of the sun's diameter, and its breadth about the one fifty-fourth part of the same diameter; consequently the length of the spots and penumbra was 41,900 miles, its breadth 16,300, and its area 6,829,700,000 square miles, which would afford room for ten globes as large as the earth to be placed upon it. It consisted of a dark spot of a longish form, about 12,000 miles in length, and two or three smaller spots, some of them several thousand miles long, all included within one penumbra. The smallest spots we can discern on the solar disk cannot be much less than five or six hundred miles in diameter.

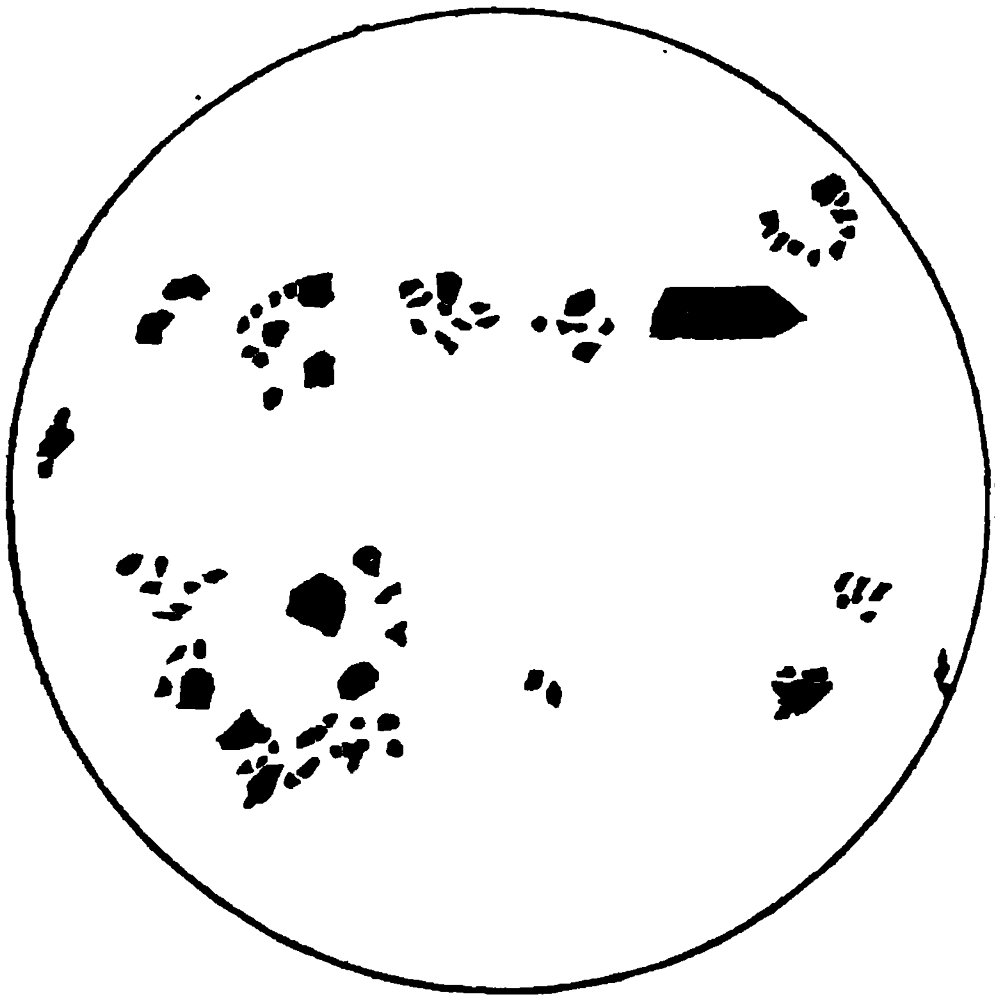
These spots *are subject to numerous changes.* When watched from day to day, they appear to enlarge or contract, to change their forms, and at length to disappear altogether, or to break out on parts of the solar surface where there were none before. Hevelius observed one which arose and vanished in the space of seventeen hours. No spot has been known to last longer than one that appeared in the year 1676, which continued upon the sun above seventy days; but it is seldom that any spots last longer than six weeks. These spots that are formed gradually are generally gradually dissolved; those which arise suddenly are, for the most part, suddenly dissolved. Dr. Long, in his "Astronomy," vol. ii. states,

that "while he was viewing the image of the sun cast through a telescope upon white paper, he saw one roundish spot, by estimation not much less in diameter than our earth, break into two, which immediately receded from one another with a prodigious velocity." The Rev. Dr. Wollaston, when viewing the sun with a reflective telescope, perceived a similar phenomenon. A spot burst in pieces while he was observing it like a piece of ice, which, thrown upon a frozen pond, breaks in pieces and slides in various directions. On the 11th of October, 1833, at $2^h\ 30'$ P. M., I observed a large spot, with several smaller ones behind it, as represented Fig. 71. Next day, at $0^h\ 30'$ P. M., the small spots marked *e* had entirely disappeared, and no trace of them was afterwards seen. Each of these spots was more than a thousand miles in diameter, yet they were all changed in the space of twenty-two hours. The spot marked *d*, near the large spot, though at least two or three thousand miles in length, disappeared about three days afterward. When any spot begins to increase or diminish, the nucleus, or dark part, and the penumbra contract and expand at the same time. During the process of diminution, the penumbra encroaches gradually upon the nucleus, so that the figure of the nucleus and the boundary between it and the penumbra are in a state of perpetual change; and it sometimes happens during these variations, that the encroachment of the penumbra divides the nucleus into two or more parts. These circumstances show that there is a certain connexion between the penumbra and the nucleus; yet it is observed, that when the spots disappear the penumbra continues for a short time visible after the nucleus has vanished. It is likewise observed that the exterior boundary of the penumbra never consists of sharp angles, but is always curvilinear, how irregular soever the outline of the nucleus may be. The portions of the sun on which spots of any description are perceived lie from thirty to fifty degrees on each side of its equator. No spots are ever seen about its polar regions, though I have sometimes seen small spots as distant from the equator as sixty degrees.

Fig. 68.

*North.*

East.



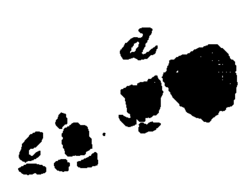
West.

*South.*

69

70

71



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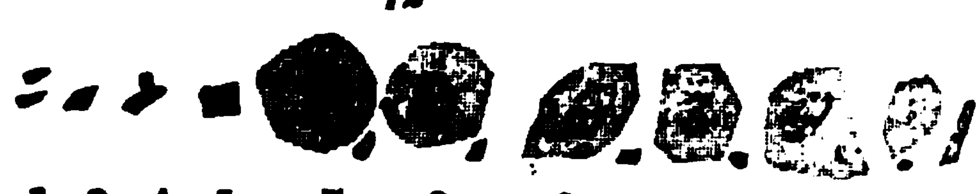
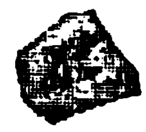


1 3 4 5 7 8 9 10 11 12 13

73

74

75



76

Fig. 72 shows the progress of a spot across the sun's disk, from its eastern to its western limb, as observed and delineated by Hevelius, in May, 1644. The figures refer to the number of days on which the spot was observed. On the first day of the observation, when the spot first appeared on the eastern limb, it was seen as represented at 1; the second day it was not visible, by reason of cloudy weather. The third, fourth, and fifth days it gradually increased in bulk; the sixth day it was not

seen. On the tenth and following days the spot was vastly increased in bulk, with an irregular atmosphere about it and a dark central spot. Figs. 73, 74, 75, 76, are representations of spots by Sir W. Herschel. Fig. 75 shows the division of a decaying nucleus or opening, where the luminous passage across the opening resembles a bridge thrown over a hollow.

Besides the dark spots now described, there are other spots which have a bright and mottled appearance, which were formerly termed *faculæ*, and which Sir W. Herschel distinguished by the terms *Nodules*, *Corrugations*, and *Ridges*. These spots are chiefly to be seen near the margin of the sun, in the same latitudes in which the other spots appear. They appear first on the eastern margin, and continue visible for three or four days, but are invisible when they arrive near the middle of the disk, and when they approach near the western limb they are again distinctly visible. This circumstance shows that they are ridges or elevations, which appear in profile when near the limb, but in front or foreshortened when near the middle of the disk, so as to become invisible. They are generally seen in the immediate neighbourhood of dark spots, and in the places where spots have appeared; and hence, for several years past, when any of these faculæ or ridges have appeared on the eastern margin, I have uniformly been enabled to predict the appearance of a large spot or two within the course of twenty-four or thirty hours; and in more than twenty or thirty instances I have never been disappointed. These faculæ and ridges present a mottled and waving appearance, like that of a country with gentle elevations and depressions, and bear a strong resemblance to certain portions of that surface of the moon, particularly the more level portions of the orb, which present a number of gentle wavings or elevations and depressions. And as those wavings or ridges which appear on the sun are, in a clear atmosphere, as distinctly perceptible as the rough surface of the moon, they must be objects of immense extent and of very great elevation, whether they consist of luminous clouds or of more dense materials. Some of those spaces or ridges have been found to occupy a portion of the solar disk equal to seventy-five thousand miles. They extend over a large portion of the sun's surface, and their shape and position are frequently changing.

*Opinions and Deductions respecting the Nature and Constitution of the Sun.*—Having described the principal phenomena connected with this immense luminary, we may now consider what conclusions those appearances lead us to deduce respecting its construction and the processes which are going on near its surface. Very vague and foolish opinions have been entertained respecting the nature of the sun ever since the invention of the telescope. It has very generally been considered as a vast body of liquid fire; and in a large volume now before me, published only about a century ago, it is considered as the local place of *hell*. A large map of the sun, copied from the delineations of *Kircher* and *Scheiner*, is exhibited, in which the solar surface is represented as all over covered with flames, smoke, volcanoes, and "great fountains, or ebullitions of fire and light, spread thick over the whole body of it; and in many places *dark spots*, representing dens or caverns, which may be supposed the seats of the blackness of darkness."* In this picture the smoke and flames are represented as rising beyond the margin of the sun about a ninth part of its diameter, or nearly 90,000 miles; a picture as unlike the real surface of the sun as the gloom of midnight is unlike the splendours of day. But, leaving such extravagant and untenable notions, even some philosophers have held opinions altogether incompatible with reason and with the phenomena presented by the sun: Galileo, Hevelius, and Maupertius considered the spots as *scoria* floating in the inflammable liquid matter of which they conceived the sun to be composed. Others have imagined that the fluid which sends forth light and heat contains a nucleus or solid globe, in which are several volcanoes, like Etna or Vesuvius which from time to time cast forth quantities of bituminous matter up to the surface of the sun, and form those spots which are seen upon it; and that, as this matter is gradually changed and consumed by the luminous fluid, the spots disappear for a time, but are seen to rise again in the same places when those volcanoes cast up new matter. Others, again, have supposed that the sun is a fiery luminous fluid, in which several opaque bodies of irregular shapes are immersed, and that these bodies are sometimes buoyed up or raised to the surface, where they appear like spots; while others imagine that this luminary consists of a fluid in continual agitation, by the rapid motion of which some parts more gross than the rest are carried up to the surface in like manner as scum rises on the top of melted metal or any thing that is boiling.

The futility of all such opinions is obvious when we consider attentively all the varieties of the solar phenomena, and when we reflect on the immense magnitude both of the sun itself and of the spots which traverse its surface. What resemblance can there be between such volcanoes as Etna and Vesuvius, and spots on the sun 20,000 miles in diame-

* "An Inquiry into the Nature and Place of Hell." By the Rev. T. Swinden, M. A., Rector of Cuxton, in Kent. 2d edit., p. 470. London, 1727.

ter, and several times larger than the whole earth? between the vast and sublime operations going forward in this magnificent globe, and "the *scum* and *scoria* of melted metal?" We err most egregiously when we attempt to compare the substances and the puny operations which we see around us on the globe we inhabit, with what takes place on so stupendous a globe as the sun, whose constitution must be so immensely different from that of the planetary bodies, and from every thing within the range of our observation on this earth. We talk of volcanoes, of scoria, of boiling metals, of bituminous matter, of dens, and caverns, and fiery flames in the sun, as if they were as common there as with us; whereas there is every reason to believe that nothing similar to any of these is to be found in the constitution of this vast luminary. We might, with as good reason, attempt to compare the process of vegetation on our globe, and the tides and currents of our ocean, with what takes place on the surface of Jupiter or on the rings of Saturn. In all such cases, it is most becoming rather to acknowledge our ignorance than to caricature and degrade the sublimest works of Omnipotence by our puerile explanations and whimsical theories. The following are some of the more rational conclusions which have been deduced in reference to the constitution of the sun.

In the first place, from a variety of observations, it is now pretty well determined that the solar spots are *depressions*, and not elevations, and that the black nucleus of every spot is the opaque body of the sun seen through an opening in the luminous atmosphere with which it is environed. This was first ascertained by numerous observations made by the late Dr. Wilson, professor of astronomy in the university of Glasgow. This conclusion is founded on the following facts: When any spot is about to disappear behind the sun's western limb, the eastern portion of the umbra first contracts in its breadth, and then vanishes. The nucleus then contracts and vanishes, while the western portion of the umbra still remains visible. When a spot comes into view on the sun's eastern limb, the eastern portion of the umbra first becomes visible, then the dark nucleus, and then the western part of the umbra makes its appearance. When two spots are near each other, the umbra of the one spot is deficient on the side next the other; and when one of the spots is much larger than the other, the union of the largest will be completely wanting on the side next the small one. From various micrometical estimates and calculations in relation to the breadth of the umbra, and the manner of their appearance and disappearance, the doctor was led to the conclusion that the *depth* of the nucleus or dark part of the spots was, in several instances, from 2000 to nearly 4000 miles. In order to confirm his theory, he constructed a globe representing the sun, with certain hollows cut out to represent the spots or excavations, which were painted black with Indian ink, and the slope or shelving sides of the excavations were distinguished from the brightness of the external surface by a shade of the pencil, which increased towards the external border. When this artificial sun was fixed in a proper frame, and examined at a great distance with a telescope, the umbra and the nucleus exhibited the same phenomena which are observed on the real sun.*

Sir William Herschel, with his powerful telescopes, made numerous observations on the solar spots, and arrived at the same conclusion as Dr. Wilson had done, that the dark nucleus of the spots is the opaque body of the sun appearing through the openings in its atmosphere, and that the luminous surface of the sun is neither a liquid substance nor an elastic fluid, but luminous or phosphoric clouds floating in the solar atmosphere. He conceives, from the uniformity of colour in the penumbra or *shallows*, that below these self-luminous clouds there is another stratum of clouds of inferior brightness, which is intended as a curtain to protect the solid and opaque body of the sun from the intense brilliancy and heat of the luminous clouds; and that "the luminous strata are sustained far above the level of the solid body by a transparent elastic medium, carrying on its upper surface, or at some considerably lower level within its depth, a cloudy stratum, which, being strongly illuminated from above, reflects a considerable portion of the light to our eyes, and forms a penumbra, while the solid body, shaded by the clouds, reflects little or none."

What, then, are the conclusions which may be deduced in regard to the constitution of the sun? In the first place, we must admit that, at present, we know very little of the nature of this immense luminary, and of the processes that are going forward on its surface or in its atmosphere. For there is no similar body with which we are intimately acquainted with which we can compare it, and which might enable us to form some definite conceptions of the causes which produce the phenomena it presents. But, secondly, it appears highly probable, if not absolutely certain, that the great body of the sun consists of an opaque solid globe, most probably diversified with elevations and depressions, but of the

* See an elaborate paper on this subject by Dr. Wilson, in vol. lxiv. of the "Philosophical Transactions;" and another, in reply to some objections of La Lande, in the volume for 1783.

nature or qualities of this interior globe, and the materials of which it is composed, we are altogether unacquainted. Thirdly, that this opaque globe is surrounded with a body of light, which it diffuses throughout the planetary system and far beyond it; but whether this light consists of phosphoric clouds in perpetual motion, or how it is produced and kept continually in action, is only matter of conjecture. But, in whatever it consists, it is pretty evident that it forms a shell or covering around the dark body of the sun of several thousand miles in thickness. Fourthly, there are stupendous motions and operations continually going forward in connexion with the surface or the luminous atmosphere of this immense body.

That extensive and amazing operations and processes are going forward on the surface of the sun, or in its immediate vicinity, appears from the immense size of both the dark and luminous spots, and the sudden and extensive changes to which they are frequently subjected. Spots have been observed on the solar disk so large as the one twentieth of the sun's diameter, and, of course, 44,000 miles in lineal extent, comprising an area of one thousand five hundred and twenty millions of square miles. Now it is known from observation that such spots seldom or never last longer than forty-four days, and, consequently, their borders must approach at the rate of at least a thousand miles every day, but in most cases with a much more rapid motion. What, then, shall we think of the motions and operations by which a large spot has been made to disappear in the course of twenty-two hours, as I have sometimes observed, yea, which have disappeared in the course of a single hour? And what shall we think of the process by which a spot as large as the earth was broken into two during the moment of observation, and made to recede from each other, as was observed both by Dr. Long and Dr. Wollaston? (See page 100.) How powerful the forces, how rapid the motions, and how extensive the changes which must have been produced in such cases! Whether we consider such changes to be produced in the solid globe of the sun, or merely in the luminous atmosphere with which it is environed, the scale on which such movements and operations must be conducted is immense, and altogether overpowering to the imagination. What should we think were we to behold the whole of the clouds which float in the earth's atmosphere dissipated in a moment; the continent of America detached from its basis and transported across the Atlantic; or the vast Pacific Ocean, in the course of a few days, overwhelming with its billows the whole of Asia, Africa, and Europe? Amazing as such changes and revolutions would appear, there are, in all probability, operations and changes, though of a very different description, taking place on the solar surface or atmosphere upon a scale of much larger extent. It is found by calculation that the smallest space containing a visible area which can be distinctly perceived on the sun with good telescopes is about 460 miles; and a circle of this diameter contains about 166,000 square miles. Now those ridges or corrugations, formerly termed *faculæ*, which are seen near the sun's margin, are more than twenty times larger than such a space; they evidently appear to be elevations and depressions on the solar surface, and are almost as distinctly perceptible as the wavings and inequalities on the surface of the moon. How immensely large and elevated, then, must such objects in reality be, when we perceive their inequalities so distinctly at the distance of ninety-five millions of miles! The elevated parts of such objects cannot be less than several hundreds of miles above the level of the valleys or depressions, and extending in length several thousands of miles. Yet, sometimes in a few days, or, at most, in a few weeks, these extensive objects are either dissipated or dark spots appear in their room.

It is evident, then, that stupendous powers are in action, and vast operations are going on in connexion with this august luminary, far surpassing every thing within the range of our contemplation in this terrestrial sphere, and of which the human mind can form no distinct conception. These operations appear to be carried forward in a systematic order, and by the regular influence of certain physical agents. But what these agents are; how they produce their effects; wherein they differ in their nature and properties from the physical agents connected with our globe; whether they be employed in keeping up a constant efflux of light and heat to the worlds which roll around; or whether their activities have any relation to intelligent beings connected with the sun, are questions which, in our present state, it is impossible to resolve. But we can easily conceive that scenes of overpowering grandeur and sublimity would be presented to view could we suppose ourselves placed in the immediate vicinity of this luminary. Were we placed within a hundred miles of the solar luminous atmosphere, where the operations which we now behold at a remote distance would be distinctly perceived, we should doubtless behold a scene of overwhelming magnificence and splendour, and a series of sublime phenomena far surpassing what "eye hath yet seen," or the mind of man can yet conceive. Were we placed within this luminous atmosphere, on the solid surface of the sun, we should doubtless con-

template a scene altogether novel, and still more brilliant and astonishing. To a spectator in this position an opening in the luminous atmosphere several thousands of miles in circumference, where none appeared before, would be presented to his view, through which the stars of heaven might possibly be perceived; and in a short time this opening would gradually close, and he would find himself again surrounded with ineffable splendour; while, at the same time, he might have a view of the physical agents by which these astonishing effects are produced. In a short time another opening of a different kind would be perceived, and other scenes and transformations would be exhibited to the view in regular succession. That such scenes would actually be exhibited is a natural deduction from the theory (which may be considered as established) that the sun consists of a solid globe, surrounded with a luminous atmosphere, and that the dark spots are the openings in that luminous fluid.

It appears, then, that the sun which we daily behold is a body of ineffable magnitude and splendour, and that the most magnificent operations are incessantly going forward on its surface or in its immediate vicinity. It is, indeed, a kind of *universe* in itself, the magnitude, and extent, and grandeur of which, and the vast and sublime operations connected with its physical constitution, surpass the powers of the human mind to form any adequate conception. We are destitute of a *substratum* of thought for enabling us to form a comprehensive conception on this subject. When we ascend to the top of Mount Etna or Mount Blanc, and survey the vast group of surrounding objects which appear around and beneath us when the morning sun illuminates the landscape, we behold one of the largest and most expansive objects that can meet our eye in this sublunary scene; and we can compare it with objects that are smaller and with those that are somewhat larger. But the amplitude of such a scene extends only to a hundred or a hundred and fifty miles in every direction, which is less than the least visible point or spot which we can perceive on the sun with the most powerful telescopes. Were we transported to a point five or six thousand miles above the surface of the earth, so as to take in nearly at one view the whole hemisphere of our globe; and were our eyes to be strengthened so as to be able to perceive every part of its surface distinctly, our ideas of *magnitude* would be vastly enlarged, and we should be enabled to form more correct and comprehensive conceptions than we can now do of the still greater magnitudes of many of the celestial bodies. But even such an object as the whole of the earth's hemisphere, seen at one comprehensive view, would afford us comparatively little assistance in forming an adequate conception of such a stupendous globe as the sun; it would not equal the idea of magnitude which we ought to attach to one of the smaller spots on its surface. For the area of the solar surface is twenty-four thousand seven hundred times greater; so that 24,700 scenes equal in magnitude to the hemisphere of our globe must pass between us in review before we could acquire a comprehensive and adequate idea of the expansive surface of the sun. And were a scene of this description to pass before our eyes every two hours, till an extent equal to the area of the sun passed under our view, and were twelve hours every day allotted for the observation, it would require more than eleven years before such a rapid survey of this vast luminary could be completed. But, as we can have no adequate idea of a scene comprehending a whole hemisphere of our globe, let us compare the view from Mount Etna with the amplitude of the sun. "There is no point on the surface of the globe," says Mr. Brydone, "that unites so many awful and sublime objects as the top of Etna, and no imagination has dared to form an idea of so glorious and magnificent a scene. The body of the sun is seen rising from the ocean, immense tracts both of sea and land intervening; the islands of Pinari, Alicudi, Lipari, Stromboli, and Volcano, with their smoking summits, appear under your feet, and you look down on the whole of Sicily as on a map, and can trace every river through all its windings from its source to its mouth. The view is absolutely boundless on every side, so that the sight is every where lost in the immensity." Yet this glorious and expansive prospect is comprised within a circle about 240 miles in diameter and 754 in circumference, containing 45,240 square miles, which is only 1-53,776,608 part of the surface of the sun; so that fifty-three millions, seven hundred and seventy-six thousand landscapes, such as beheld from Mount Etna, behooved to pass before us before we could contemplate a surface as expansive as that of the sun; and if every such landscape were to occupy two hours in the contemplation, as supposed above, it would require *twenty-four thousand five hundred and fifty-four years* before the whole surface of this immense globe could be in this manner surveyed; and, after all, we should have but a very imperfect conception of the *solid contents* of the sun, which contains 356,818,739,200,000,000 of cubical miles, which number is 146,670 times greater than the number of square miles upon its surface.

What a glorious idea, then, does such an object as the sun present to us of the Gran-

DEUR of the Deity and the ENERGIES of OMNIPOTENCE! There is no single object within the range of our knowledge that affords a more striking and august emblem of its Great Creator. In its lustre, in its magnitude, in its energy, in its boundless influence, and its beneficial effects on this earth and on surrounding worlds, there is a more bright display of Divine perfection than in any other material being with which we are acquainted:

"Great source of day! best image here below
Of thy Creator! ever pouring wide
From world to world, the vital ocean round,
On Nature write, with every beam, his praise."

Could such a magnificent orb have been produced by a fortuitous concourse of atoms, and placed in its proper position to distribute light and attractive influence to the worlds which roll around it? Could chance have directed the distance at which it should be placed from the respective planets, or the size to which it should be expanded, in order to diffuse its energies to the remotest part of the system? Could chance have impressed upon it the laws requisite for sustaining in their courses all the bodies dependent upon it, or have endowed it with a source of illumination which has been preserved in action from age to age? To affirm such positions would be to undermine and annihilate the principles of all our reasonings. The existence of the sun proves the existence of an Eternal and Supreme Divinity, and at the same time demonstrates his omnipotent power, his uncontrollable agency, the depths of his wisdom, and the riches of his beneficence. If such a luminary be so glorious and incomprehensible, what must its Great Creator be? If its splendour be so dazzling to our eyes, and its magnitude so overpowering to our imagination, what must He be who lighted up that magnificent orb, and bade a retinue of worlds revolve around it; who "dwells in light inaccessible, to which no mortal eye can approach?" If the sun is only one out of many myriads of similar globes dispersed throughout the illimitable tracts of creation, how great, how glorious, how far surpassing human comprehension must be the plans and the attributes of the infinite and eternal Creator! "His greatness is unsearchable, and his ways past finding out." Could we thoroughly comprehend the depths of his perfections or the grandeur of his empire, he would cease to be God, or we should cease to be limited and dependent beings. But, in presenting to our view such magnificent objects, it is evidently his intention that we should rise in our contemplations from the effect to the cause, from the creature to the Creator, from the visible splendours and magnificence of creation to the invisible glories of Him who sits on the throne of the universe, "whose kingdom ruleth over all, and before whom all nations are counted as less than nothing and vanity."

It might here form a subject of inquiry, *whether there be any reason to believe that the sun is inhabited?* Most astronomers have been disposed to answer this question in the negative. Sir W. Herschel, however, and several others, consider it as not altogether improbable that the sun is peopled with rational beings. Viewing this luminary as consisting of a dark solid nucleus, surrounded by two strata of clouds, the outermost the region of that light and heat which is diffused to the remotest parts of the system, they conceived that the interior stratum was intended to protect the inhabitants of the sun from the fiery blaze of the sphere of light and heat with which they are surrounded. On either side of this question it becomes us to speak with diffidence and modesty. We ought not to set limits to the wisdom and arrangements of the Creator by affirming that rational beings could not exist and find enjoyment on such a globe as the sun, on account of the intensity of light and heat which for ever prevails in that region. For it is probable that the luminous matter that encompasses the solid globe of the sun does not derive its splendour from any intensity of heat. If this were the case, the parts underneath, which are perpetually in contact with that glowing matter, would be heated to such a degree as to become luminous and bright, whereas we find that they have uniformly a *dark* appearance: so that it is possible the interior region of the sun may be in a state of comparatively low temperature. For any thing we know to the contrary or can demonstrate, the sun may be one of the most splendid and delightful regions of the universe, and scenes of magnificence and grandeur may be there displayed far surpassing any thing that is to be found in the planets which revolve around it, and its population may as far exceed in number that of other worlds as the immense size of this globe exceeds that of all the other bodies in the system. But, on the other hand, we know too little of the nature and constitution of the sun, and the plans of Divine Wisdom, to warrant us to make any positive assertions on this point. Although no intelligent beings were connected with this great luminary, its boundless influence in the planetary system; its being the soul and centre of surrounding worlds; its diffusing light, and heat, and genial influences of various kinds, to all the tribes of their inhabitants; and its cementing them all by its attractive energy in one harmonious system, are reasons sufficient for the creation of this vast globe, without the influence of which perpetual darkness would en-

sue, the planets would start from their spheres, and the whole system soon become one universal wreck.

It is owing to the existence of the sun that our globe is a habitable world and productive of enjoyment. Almost all the benign agencies which are going forward in the atmosphere, the waters, and the earth, derive their origin from its powerful and perpetual influence. Its light diffuses itself over every region, and produces all that diversity of colouring which enlivens and adorns the landscape of the world, without which we should be unable to distinguish one object from another. By its vivifying action, vegetables are elaborated from inorganic matter, the sap ascends through their myriads of vessels, the flowers glow with the richest hues, the fruits of autumn are matured, and become, in their turn, the support of animals and of man. By its heat the waters of the rivers and the ocean are attenuated and carried to the higher regions of the atmosphere, where they circulate in the form of vapour till they again descend in showers, to supply the sources of the rivers and to fertilize the soil. By the same agency all winds are produced, which purify the atmosphere by keeping it in perpetual motion, which propel our ships across the ocean, dispel noxious vapours, prevent pestilential effluvia, and rid our habitations of a thousand nuisances. By its attractive energy the tides of the ocean are modified and regulated, the earth conducted in its annual course, and the moon sustained and directed in her motions. Its influence descends even to the mineral kingdom, and is felt in the chymical compositions and decompositions of the elements of nature. The disturbances in the electric equilibrium of the atmosphere, which produce the phenomena of thunder, lightning, and rain, and the varieties of terrestrial magnetism; the slow degradation of the solid constituents of the globe and their diffusion among the waters of the ocean, may all be traced, either directly or indirectly, to the agency of the sun. It illuminates and cheers all the inhabitants of the earth from the polar regions to the torrid zone. When its rays gild the eastern horizon after the darkness of the night, something like a new creation appears. The landscape is adorned with a thousand shades and colours; millions of insects awake and bask in its rays; the birds start from their slumbers, and fill the groves with their melody; the flocks and herds express their joy in hoarser acclamations; "man goeth forth to his work and to his labour;" all nature smiles, and "the hills rejoice on every side." Without the influence of this august luminary, a universal gloom would ensue, and surrounding worlds, with all their trains of satellites, would be shrouded in perpetual darkness. This earth would become a lifeless mass, a dreary waste, a rude lump of inactive matter, without beauty or order. No longer should we behold the meadows clothed with verdure, the flowers shedding their perfumes, or "the valleys covered with corn." The feathered songsters would no longer chant their melodious notes; all human activity would cease; universal silence would reign undisturbed, and this huge globe of land and water would return to its original chaos.

Hence it appears that there is a sufficient reason for the creation of this powerful luminary, although no sensitive or intelligent beings of any description were placed on its surface. But, at the same time, when we consider the infinite wisdom and intelligence of the Divine mind, and that the thoughts and the ways of God as far surpass the thoughts of man as the heavens in height surpass the earth; when we consider that animated beings on our own globe are found in situations where we should never have expected them; that every puddle and marsh, and almost every drop of water, is crowded with living beings; and that even the very viscera in the larger animals can afford accommodation for sentient existence, it would be presumptuous in man to affirm that the Creator *has not placed* innumerable orders of sentient and intelligent beings, with senses and constitutions accommodated to their situations, throughout the expansive regions of the sun.

It has been a question which has exercised the attention of some astronomers, *whether the solar phenomena have any effect upon the weather*, or the productiveness of our seasons. Sir W. Herschel was of opinion, that when the corrugations and openings of the solar atmosphere are numerous, the heat emitted by the sun must be proportionably increased, and that this augmentation must be perceptible by its effects on vegetation; and, by comparing the solar appearances as given by La Lande with the table of the price of wheat in Smith's "Wealth of Nations," he obtained results which he considered as favourable to his hypothesis. But it is evident that we are not yet in possession of such a series of facts in relation to this subject as will warrant us to draw any general conclusions. Besides, we know too little of the construction of the sun, and the nature of those processes which are going on in its atmosphere, to be able to determine the proportion of light and heat which particular phenomena indicate. So far as my own observation goes, I should be disposed to adopt an opposite conclusion, namely, that in those years when the spots of the sun are numerous, the seasons are colder and more unproductive of vegetation. This was remarkably the case

in the year 1816, when the solar spots were extremely numerous, and when the harvest was so late and scanty that the price of all kinds of grain was more than double what it had been before or what it has been since. The year 1836, and the present year, 1837, afford similar examples; for, during eighteen months past, the solar spots have been more numerous than in any other period in my recollection; and the cold of the summer and harvest of 1836, and of the winter and spring of 1837, and its unfavourable effects on vegetation, were greater than what had been experienced for more than twenty years before. But on this point we are not yet warranted to draw any positive conclusions. Before we can trace any general connexion between the solar spots and the temperature and vegetation of our globe in any particular season, we must endeavour to ascertain the effects produced on vegetation not only in two or three particular countries which lie adjacent to each other, but over all the regions of the earth. It may be proper to direct our future observations to this point, as they might probably lead to some important results; but a considerable period behooved to elapse before we could be warranted to deduce any definite conclusions.

*Whether the sun has a progressive motion in absolute space* is another question which has engaged the attention of astronomers. If the sun have such a motion directed to any quarter of the heavens, the stars in that quarter must apparently recede from each other, while those in the opposite region will seem gradually to approach. Sir W. Herschel found that the apparent proper motion of forty-four stars out of fifty-six are very nearly in the direction which should result from a motion of the sun towards the constellation *Hercules*, or to a point of the heavens whose right ascension is 250° 52½′, and north declination 49° 38′. "No one," says Sir John Herschel, "who reflects with due attention on the subject, will be inclined to deny the high probability, nay, *certainty*, that the sun *has* a proper motion in *some* direction." But it appears to be yet undetermined by modern astronomers to what point in the heavens this motion is directed, and whether it be in a straight line or in a portion of the circumference of an immense circle. If the sun, then, has a proper motion in space, all the planetary bodies and their satellites, along with the comets, must partake of it; so that, besides their own proper motions around this luminary, they are likewise carried along with the sun through the depths of infinite space with a velocity perhaps as great as that with which they are carried round in their orbits. Our earth will therefore partake of three motions: one round its axis, another round the sun, and a third in the direction in which the sun is moving, and, consequently, it is probable that we shall never again occupy that portion of absolute space through which we are now passing throughout all the succeeding periods of eternity.

*The Zodiacal Light.*—The zodiacal light is a phenomenon which has been generally considered as connected with the sun. The light appears to have been noticed by Mr. Childrey about the year 1660; but it was afterward more particularly noticed and described by Cassini in the spring of 1683, which was the first time he had seen it, and he observed it for about eight days. It appears generally in a conical form, having its base directed towards the body of the sun and its point towards some star in the zodiac. Its light is like the milky way, or that of the faint twilight, or the tail of a comet, thin enough to let the stars be seen through it, and seems to surround the sun in the form of a lens, the plane of which is nearly coincident with the plane of the sun's equator. The apparent angular distance of its vertex from the sun varies from 40 to 90 degrees, and the breadth of its base, perpendicular to its axis, from 8 to 30 degrees. It is supposed to extend beyond the orbit of Mercury, and even as far as that of Venus, but never so far as the orbit of the earth. This light is weaker in the morning when day is coming on than at night when darkness is increasing, and it disappears in full moonlight or in strong twilight. In north latitudes it is most conspicuous after the evening twilight about the end of February and the beginning of March; and before the appearing of the morning twilight, about the beginning of October; for at those times it stands most erect above the horizon, and is therefore furthest removed from the thick vapours and the twilight. About the time of the winter solstice it may likewise be seen in the mornings; but it is seldom perceptible in summer on account of the long twilights. It is more easily and more freqently perceived in tropical climates, and particularly near the equator, than in our country, because in those parts the obliquity of the equator and zodiac to the horizon is less, and because the duration of twilight is much shorter. Humboldt observed this light at Caraccas on the 18th of January, after seven o'clock in the evening. The point of the pyramid was at the height of 53 degrees; and the light totally disappeared about half past nine, about 3¾ hours after sunset, without any diminution in the serenity of the sky. On the 15th of February it disappeared 2 hours and 50 minutes after sunset, and the altitude of the pyramid on both these occasions was 50 degrees. The following figure exhibits a view

of this phenomenon as it is seen about the beginning of March, at seven o'clock in the evening,

Fig. 77.


when the twilight is ending, and the equinoctial point in the horizon. *A B* represents the horizon; *C D* the base of the luminous triangle; and *E* its apex, pointing towards the Pleiades or the star Aldebaran, its axis forming an angle of between 60 and 70 degrees with the horizon.

Various opinions have been entertained as to the cause of this phenomenon; but as it uniformly accompanies the sun, it has been generally ascribed to an atmosphere of immense extent surrounding that luminary, and extending beyond the orbit of Mercury. According to this opinion, the zodiacal light is considered as a section of this atmosphere; but this opinion now appears extremely dubious. Professor Olmsted, of Yale College, the celebrated Arago, Biot, and others, are now disposed to identify this phenomenon with the cause that produces the "November Meteors," or shooting stars, which have, of late, excited so great a degree of public attention. It appears highly probable that these meteors derive their origin from a nebulous body which revolves round the sun, and which, in certain parts of its course, comes very near the orbit of the earth, so as to be within its attractive power; and if such a body be the source whence these meteors proceed, it may also account for the phenomena of the zodiacal light. The subject is worthy of particular attention, and future observations may not only throw light on this particular phenomenon, but open to our view a species of celestial bodies with which we were formerly unacquainted.

## CHAPTER IV.

### *On the secondary Planets or Moons.*

Having, in the preceding chapter, given a detailed account of the phenomena connected with the sun and the primary planets of our system, I shall now proceed to a brief description of what is known in reference to the satellites or moons which accompany several of the primary planets.

A secondary planet or satellite is a body which revolves around a primary planet as the centre of its motion, and which is at the same time carried along with its primary round the sun. The satellites form a system, in connection with their primaries, similar to that which the planets form in connexion with the sun. They revolve at different distances from their primaries; they are regulated according to the laws of Kepler formerly alluded to; their orbits are circles or ellipses of very moderate eccentricity; in their motions around their primaries they describe areas very nearly proportional to the times; and the squares of the periodical times of all the satellites belonging to each planet are in proportion to each other as the cubes of their distances, (see page 27.) The planets around which satellites have been discovered are, the earth, Jupiter, Saturn, and Uranus. Of the satellites belonging to these bodies I shall present a brief sketch in the order in which they are here mentioned.

#### I. OF THE EARTH'S SATELLITE, OR THE MOON.

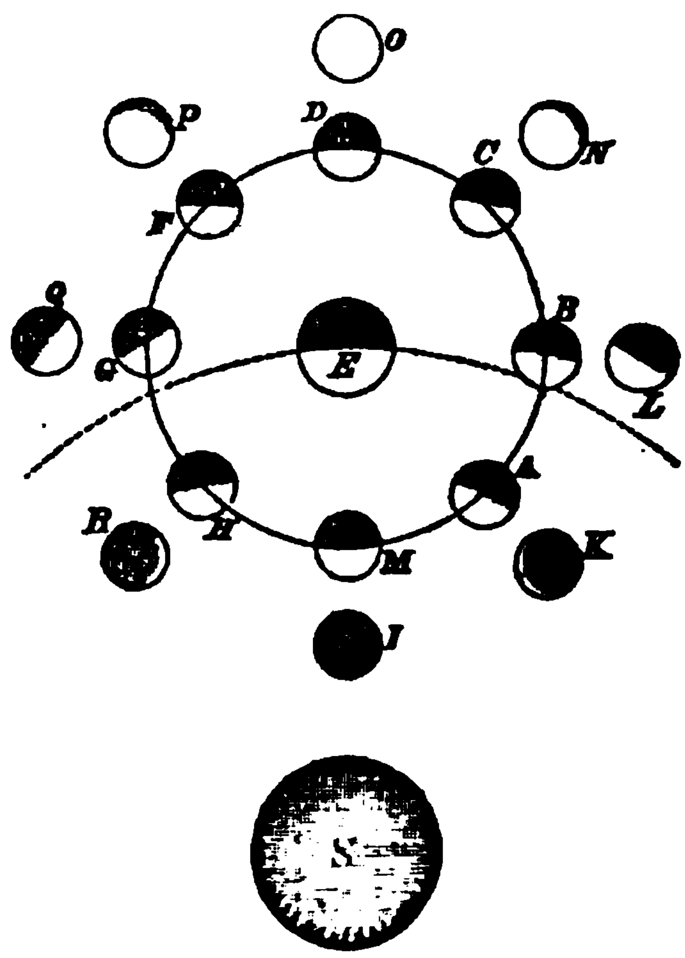
Before proceeding to a particular description of this nocturnal luminary, I shall present a brief sketch of its *apparent motions.*

The moon, like all the other celestial bodies, appears daily to rise in an easterly direction, and to set in the western parts of the horizon. Its apparent motion in this respect is similar to that of the sun, formerly described, and is owing to the diurnal motion of the earth. Its *real motion* round the earth is in a contrary direction, namely, from west to east, or in the same direction in which all the planets move round the sun. This motion may be traced every lunation, but more distinctly during the spring months, when the moon, in the first quarter, appears in a high degree of north declination, and when its crescent is sometimes visible within thirty-six hours of the change. About this period, on the second or third day of the moon's age, it will be seen in the west after sunset at a small elevation above the horizon, and exhibiting the form of a

slender crescent. On the next evening it will appear at a still higher elevation at the same hour, having moved about thirty degrees further to the east, and its crescent will appear somewhat larger. Every succeeding day it will appear at a greater elevation, and further to the east than before, and its crescent will appear larger, till about the seventh or eighth day, when it will be seen in the south when the sun is setting in the west, at which time it assumes the appearance of a semicircle, or half moon. During this period the horns of the crescent point towards the east, the enlightened part of the lunar disk being turned towards the sun. After the first quarter, or the period of half moon, the lunar orb still keeps on its course to the eastward, and the portion of its enlightened disk is gradually enlarged, till about the fifteenth day of the moon's age, when it appears as a full enlightened hemisphere, and rises in the east about the time when the sun is setting in the west. In this position it is said to be in *opposition* to the sun, and passes the meridian about midnight. After this period the enlightened part of its disk gradually diminishes, and it rises at a late hour, till, in the course of seven days, it is again reduced to a semicircle, and is seen only during one half of the night. Some nights after it appears reduced to a crescent, having its points or horns turned towards the *west*, the sun being then to the east of it. After this it rises but a little time before the sun, and is seen only early in the morning; and its crescent daily diminishes till it at length disappears, when it rises at the same time with the sun; and after having been invisible for two or three days, it reappears in the evening in the west a little after sunset. During this period the moon has made a complete circuit round the heavens from west to east, which is accomplished in twenty-nine days and a half, in which period it passes through all the phases now described. The progressive motion from west to east, every day, may be traced by observing the stars which lie nearly in the line of the moon's course. If a star be observed considerably to the eastward of the moon on any particular evening, on the following evening it will appear about thirteen degrees nearer the star, and will afterward pass to the eastward of it, and every succeeding day will approach nearer to all the other stars which lie near the line of its course to the eastward. The reason why the moon appears under the different phases now described will appear from the following figure.

In this diagram *S* represents the sun; *E* the earth; and *M, A, B, C, D, F, G, H,* the moon in different positions in its orbit round the earth. When the moon is at *M,* as seen from the earth, her dark side is completely turned to the earth; and she is consequently invisible, as at *I,* being nearly in the

Fig. 78.




same part of the heavens with the sun. She is in this position at the period termed *new moon,* when she is also said to be *in conjunction* with the sun. When she has moved from *M* to *A* a small part of her enlightened hemisphere is turned towards the earth, when she appears in the form of a *crescent,* as at *K.* In moving from *A* to *B* a larger portion of her enlightened hemisphere is gradually turned towards the earth; and when she arrives at *B* the one half of her enlightened hemisphere is turned to the earth, and she assumes the figure of a *half moon,* as at *L.* When arrived at *C* she appears under what is called a *gibbous* phase, as at *N,* more than one half of her enlightened disk being turned to the earth. At *D* her whole enlightened hemisphere is turned to our view, and she appears a *full moon,* as at *O.* After this period she again decreases, turning every day less and less of her enlightened hemisphere to the earth, so that at *F* she appears as at *P*; at *G* a half moon on the decline, as at *Q*; at *H* a crescent, as at *R*; and at *M* she is again in conjunction with the sun, when her dark side is turned to the earth as before. The moon passes through all these changes in twenty-nine days, twelve hours, and forty-four minutes, at an average, which is termed her *synodical revolution.* But the time which she takes in making one revolution round the earth, from a fixed star to the same again, is only twenty-seven days, seven hours, and forty-three minutes, which is called her *periodical revolution.* For, after

one revolution is finished, she has a small arc to describe in order to get between the sun and the earth; because, in consequence of the earth's motion in the same direction, the sun appears to be advancing forward in the ecliptic, and, of course, the moon requires some time to overtake him, after having finished a revolution. This surplus of motion occupies two days, five hours, and one minute, which, added to the periodical, make the synodical revolution, or the period between one new or full moon and another. This might be illustrated by the revolution of the hour and minute-hands of a watch or clock. Suppose the hour-hand to represent the sun, and a complete revolution of it to represent a year; suppose the minute-hand to represent the moon, and its circuit round the dial-plate a month, it is evident that the moon or minute-hand must go more than round the circle where it was last conjoined with the sun or hour-hand before it can again overtake it. If, for example, they were in conjunction at 12, the minute-hand or moon must make a complete revolution and above one-twelfth before they can meet, a little past I.; for the hour-hand, being in motion, can never be overtaken by the minute-hand at that point from which they started at their last conjunction.

To a spectator placed on the lunar surface, the earth would every month exhibit all the phases of the moon, but in a reverse order from what the moon exhibits to the earth at the same time. Thus (Fig. 78,) when the moon is at $D$ only the dark hemisphere of the earth is turned towards the moon, and, consequently, the earth would be then invisible; so that when it is full moon to us, it is new moon to a lunar inhabitant; as the earth will then be in conjunction with the sun, and nothing but its dark hemisphere presented to view. When the moon is at $P$ a small portion of the enlightened half of the earth is turned towards the moon, and it appears as a crescent. When she is at $Q$ the earth appears as a half moon; when at $R$ a gibbous phase; and when she is at $I$, the time of new moon to us, the earth then shines on the dark side of the moon with a full enlightened hemisphere. It is owing to this circumstance, that when the new moon first appears like a slender crescent, her dark hemisphere is seen illuminated with a faint light, perceptible even to the naked eye; and with the help of a telescope we are enabled, by this faint illumination, to distinguish the prominent spots on this portion of the lunar disk. This faint light, therefore, is nothing else than *the moonlight of the moon*, produced by the earth shining with nearly a full face upon the dark surface of the moon. And as the surface of the earth is thirteen times larger than the surface of the moon, the light reflected from the earth will be nearly equal to that of thirteen full moons. As the age of the moon increases, this secondary light is gradually enfeebled, and after the seventh or eighth day from the change it is seldom visible. This arises from the diminution of the enlightened part of the earth, which then appears only like a half moon, approaching to a crescent, and, consequently, throws a more feeble light upon the moon, which is the more difficult to be perceived as the enlightened part of the moon increases.

*Rotation of the Moon.*—While the moon is performing her revolution round the earth every month, she is also gradually revolving round her axis; and it is somewhat remarkable that her revolution round her own axis is performed *in the same time* as her revolution round the earth. This is inferred from the circumstance that *the moon always turns the same face to the earth*, so that we never see the other hemisphere of this globe. For if the moon *had no rotation upon an axis*, she would present every part of her surface to the earth. This does not, at first sight, appear obvious to those who have never directed their attention to the subject. Any one, however, may convince himself of the fact by standing in the centre of a circle, and causing another person to carry round a terrestrial globe, without turning it on its axis, when he will see every part of the surface of the globe in succession; and in order that one hemisphere only should be presented to his view, he will find that the globe will require to be gradually turned round its axis, so as to make a complete rotation during the time it is carried round the circle. The axis of the moon is inclined 88° 29′ to the ecliptic, so that it is nearly perpendicular to it. Although the moon presents nearly the same side to the earth in all its revolutions around it, yet there is perceived a certain slight variation in this respect. When we look attentively at the disk of the moon with a telescope, we sometimes observe the spots on her eastern limb, which were formerly visible, concealed behind her disk, while others appear on her western limb which were not seen before. The spots which appear on the western limb withdraw themselves behind the limb, while the spots which were concealed behind the eastern limb again appear. The same phenomena are observed in the north and south limb of the moon, so that the spots sometimes change their positions about three minutes on the moon's disk, or about the eleventh part of her diameter. This is termed *the libration of the moon;* the one her libration in *longitude*, and the other her libration in *latitude*.

From what we have stated above in relation to the phases and motions of the moon,

it is evident that the moon is a dark body, like the earth, and derives all its light from the sun, for its enlightened side is always turned towards that luminary. It likewise derives a faint light by the reflection of the sun's rays from the earth, in the same way as we derive a mild light from the moon. And as the earth has an uneven surface, composed of mountains and vales, so the moon is found to be diversified with similar inequalities. It is owing to these inequalities, or the *roughness* of the moon's surface, that the light of the sun is reflected from it *in every direction;* for, if the surface of the moon were perfectly smooth, like a polished globe or speculum, her orb would be invisible to us; except, perhaps, at certain times, when the image of the sun, reflected from it, would appear like a bright lucid point. This may be illustrated by the following experiment. Place a silver globe, perfectly polished, about two inches diameter, in the sun; the rays which fall upon it being reflected variously, according to their several incidences, upon the convex surface, will come to our eye only from one point of the globe, which will therefore appear a small bright spot, but the rest of the surface will appear dark. Let this globe then be boiled in the liquor used for whitening silver, and placed in the sun; it will appear in its full dimensions all over luminous; for the effect of that liquor is to take off the smoothness of the polish, and make the surface rough, and then every point of it will reflect the rays of light in every direction.

The moon is nearest to the earth of all the celestial bodies, and is a constant attendant upon it at all seasons. Her distance from the centre of the earth is, in round numbers, 240,000 miles, or somewhat less than a quarter of a million; which is little more than the fourth part of the diameter of the sun. Small as this distance is compared with that of the other planets, it would require five hundred days, or sixteen months and a half, for a steam-carriage to move over the interval which separates us from the lunar orb, although it were moving day and night at the rate of twenty miles every hour. In her motion round the earth every month, she pursues her course at the rate of 2300 miles an hour. But she is carried at the same time, along with the earth, round the sun every year, so that her real motion in space is much more rapid than what has now been stated; or while she accompanies the earth in its motion round the sun, which is at the rate of 68,000 miles an hour, she also moves thirteen times round the earth during the same period, which is equal to a course of nearly twenty millions of miles.

The moon's orbit is inclined to the ecliptic in an angle of 5° 9′; so that, in one part of her course, she is above, and in another below the level of the earth's orbit. It is owing to this circumstance that this orb is not eclipsed at every full moon and the sun at every new moon, which would regularly happen did the moon move in an orbit exactly coincident with the plane of the ecliptic. The moon's orbit, of course, crosses the orbit of the earth in two opposite points, called her *nodes;* and it is only when the new or full moon happens at or near these nodes that an eclipse of the sun or moon can take place; for it is only when she is in such a position that the sun, the moon, and the earth are nearly in a straight line, and that the shadow of the one can fall upon the other. The shadow of the moon falling upon any part of the earth produces an eclipse of the sun, and the shadow of the earth falling upon the moon causes an eclipse of the moon. An eclipse of the moon can only take place at *full moon,* when the earth is between the sun and the moon; and an eclipse of the sun can only happen at *new moon,* when the moon comes between the sun and the earth. Lunar eclipses are visible in all parts of the earth which have the moon above their horizon, and are every where of the same magnitude and duration; but a solar eclipse is never seen throughout the whole hemisphere of the earth where the sun is visible; as the moon's disk is too small to hide the whole, or any part of the sun from the whole disk or hemisphere of the earth. Nor does an eclipse of the sun appear the same in all parts of the earth where it is visible, but when in one place it is total, in another it is only partial.

The moon's orbit, like those of the other planets, is in the form of an *ellipse,* the *eccentricity* of which is 12,960 miles, or about 1-37 part of its longest diameter. The moon is, therefore, at different distances from the earth in different parts of her orbit. When at the greatest distance from the earth, she is said to be in her *apogee;* when at the least distance, in her *perigee.* The nearer the moon is to the periods of *full* or *change,* the greater is her velocity; and the nearer to the quadratures, or the periods of half moon, the slower she moves. When the earth is in its *perihelion,* or nearest the sun, the periodical time of the moon is the greatest. The earth is at its perihelion in winter, and, consequenly, at that time the moon will describe the largest circle about the earth, and her periodical time will be the longest; but when the earth is in its *aphelion,* or furthest from the sun, which happens in summer, she will describe a smaller circle, and her periodical time will be the least, all which circumstances are found to agree with observation. These

and many other irregularities in the motion of this orb, which it would be too tedious to particularize, arise from the attractive influence of the sun upon the lunar orb in different circumstances and in different parts of its course, so as to produce different degrees of accelerated and retarded motion. The irregularities of the moon's motion have frequently puzzled astronomers and mathematicians, and they render the calculations of her true place in the heavens a work of considerable labour. No less than thirty equations require to be applied to the *mean* longitude in order to obtain the *true*, and about twenty-four equations for her latitude and parallax; but to enter minutely into such particulars would afford little satisfaction to general readers.

*Description of the surface of the Moon, as seen through telescopes.*—Of all the celestial bodies, the telescopic view of the moon presents the most interesting and variegated appearance. We perceive, as it were, a map or model of another world, resembling in some of its prominent features the world in which we dwell, but differing from it in many of its minute arrangements. It bears a certain analogy to the earth in some of the mountains and vales which diversify its surface; but the general form and arrangement of these elevations and depressions, and the scenery they present to a spectator on the lunar surface, are very different from what we behold in our terrestrial landscapes. When we view the moon with a good telescope when about three days old, we perceive a number of elliptical spots with slight shadows, evidently indicating elevations and depressions; we also perceive a number of bright specks or studs in the dark hemisphere, immediately adjacent to the enlightened crescent, and the boundary between the dark and the enlightened portion of the disk appears jagged and uneven. At this time, too, we perceive the dark part of the moon covered with a faint light; so that the whole circular outline of the lunar hemisphere may be plainly discerned. When we take a view of the lunar surface, at the period of half moon, we behold a greater variety of objects, and the shadows of the mountains and caverns appear larger and more prominent. This is, on the whole, the best time for taking a telescopic view of the surface of the moon. When we view her when advanced to a gibbous phase, we see a still greater extent of the surface, but the shadows of the different objects are shorter and less distinct. At the time of full moon, no shadows either of the mountains or caverns are perceptible, but a variety of dark and bright streaks and patches appear distributed in different shapes over all its surface. If we had no other view of the moon but at this period, we should scarcely be able to determine whether mountains and vales existed on this orb. The view of the *full* moon, therefore, however beautiful and variegated, can give us no accurate idea of the mountains, vales, caverns, and other geographical arrangements which diversify its surface.

*Lunar Mountains.*—That the surface of the moon is diversified with mountains or high elevations, is evident from an inspection of its disk, even with a common telescope. They are recognized from various circumstances. 1. From the appearance of the boundary which separates the dark from the enlightened hemisphere of the moon. This boundary is not a straight line or a regular curve, as it would be if the moon were a perfectly smooth globe, but uniformly presents an uneven or jagged appearance, cut, as it were, into numerous notches and breaks somewhat resembling the teeth of a saw, which appearance can only be produced by elevations and depressions on the lunar surface (Fig. 79.) 2. Adjacent to the boundary between light and darkness, and *within* the dark part of the

Fig. 79.

moon, there are seen, in almost every stage of the moon's increase and decrease, a number of *shining points* like stars, completely separated from the enlightened parts, and sometimes other small spaces or streaks which join to the enlightened surface, but run out into the dark side, which gradually change their figure till at length they come wholly within the enlightened boundary. These shining points or streaks are ascertained to be the tops or highest ridges of mountains which the sun first enlightens before his rays can reach the valleys; just as the beams of the rising sun irradiate our mountain tops before the lower parts of the landscape are enlightened.

Fig. 80.



Fig. 81.

3. The *shadows* of the mountains, when they are fully enlightened, are distinctly seen near the border of the illuminated part of the moon, as the shadows of elevated objects are seen on the terrestrial landscape. These shadows are longest and most distinctly marked about the time of half moon; and they grow shorter as the lunar orb advances to the period of full moon, in the same way as the shadows of terrestrial objects in summer gradually shorten as the sun approaches the meridian. These considerations demonstrate, beyond the possibility of doubt, that mountains of very considerable altitude and in vast variety of forms abound in almost every region of the moon.

Fig. 82.

The lunar mountains in general exhibit an arrangement and an aspect very different from the mountain scenery of our globe. They may be arranged into the four following varieties: 1. *Insulated mountains*, which rise from plains nearly level, like a sugar loaf placed on a table, and which may be supposed to present an appearance somewhat similar to Mount Etna or the peak of Teneriffe. The shadows of these mountains, in certain phases of the moon, are as distinctly perceived as the shadow of an upright staff when placed opposite to the sun; and their heights can be calculated from the length of their shadows. The heights and the length of the base of more than seventy of these mountains have been calculated by M. Schroeter, who had long surveyed the lunar face with powerful telescopes, and who some time ago published the result of his observations in a work entitled "Fragments of Selenography." Thirty of these insulated mountains are from 2 to 5 miles in perpendicular height; thirteen are above 4 miles; and about forty are from a quarter of a mile to two miles in altitude. The length of their bases varies from 3½ to 96 miles in extent. Some of these mountains will present a very grand and picturesque prospect around the plains in which they stand. 2. *Ranges of mountains*, extending in length two or three hundred miles. These ranges bear a distant resemblance to our Alps, Apennines, and Andes, but they are much less in extent, and do not form a very prominent feature of the lunar surface. Some of them appear very rugged and precipitous, and the highest ranges are, in some places, above four miles in perpendicular altitude. In some instances they run nearly in a straight line from north-east to south-west, as in that range called the *Apennines;* in other cases they assume the form of a semicircle or a crescent. 3. Another class of the lunar mountains is the *circular ranges* which appear on almost every part of the moon's surface, particularly in its southern regions. This is one of the grand peculiarities of the lunar ranges, to which we have nothing similar in our terrestrial arrangements. A plain, and sometimes a large cavity, is surrounded with a circular ridge of mountains, which encompasses it like a mighty rampart. These annular ridges and plains are of all dimensions, from a mile to forty or fifty miles in diameter, and are to be seen in great numbers over every region of the moon's surface. The mountains which form these ridges are of different elevations, from one fifth of a mile to 3½ miles in altitude, and their shadows sometimes cover the one half of the plain. These plains are sometimes on a level with the general surface of the moon, and in other cases they are sunk a mile or more below the level of the

ground which surrounds the *exterior* circle of the mountains. In some of these circular ridges I have perceived a narrow *pass* or opening, as if intended to form an easy passage or communication between the interior plain and the regions beyond the exterior of the mountains. 4. The next variety is the *central mountains*, or those which are placed in the middle of circular plains. In many of the plains and cavities surrounded by annular mountains there is an insulated mountain, which rises from the centre of the plain, and whose shadow sometimes extends, in a pyramidal form, across the semidiameter of the plain to the opposite ridges. These central mountains are generally from half a mile to a mile and a half in perpendicular altitude. In some instances they have two and sometimes three separate tops, whose distinct shadows can be easily distinguished. Sometimes they are situated towards one side of the plain or cavity, but, in the great majority of instances, their position is nearly or exactly central. The lengths of their bases vary from five to about fifteen or sixteen miles.

The preceding figures may perhaps convey a rude idea of some of the objects now described; but it is impossible, by any delineations, to convey an idea of the peculiarities and the vast variety of scenery which the lunar surface presents, such as is exhibited by a powerful telescope during the different stages of the increase and decrease of the moon.

Fig. 79 represents the moon in a crescent phase, for the purpose of showing how the enlightened tops of the mountains appear on the dark part of the moon, detached as it were from the enlightened part, and likewise to show how the boundary between the light and darkness appears jagged and uneven, indicating the existence of elevations and depressions upon its surface. Fig. 80 represents a circular or elliptical range of mountains, surrounding a plain of the same shape, where the shadow of that side of the range which is opposite to the sun appears covering the half of the plain. Fig. 81 represents a circular plain, with the shadow of one side of the mountains which encompass it, and a *central* mountain with its shadow in the same direction. Fig. 82 exhibits another of these circular ridges and plains. Several hundreds of these circular cavities and plains are distributed over the lunar surface, but they are most abundant in the southern regions.

Fig. 83.

*North.*

Fig. 83 exhibits a pretty correct view of the full moon, as seen through a telescope magnifying above a hundred times, in which the darker shades represent, for the most part, the *level* portions of the moon's surface, and the lighter shades those which are more elevated or mountainous. The bright spot near the bottom, from which streaks or streams of light seem to proceed, is called *Tycho* by some, and *Mount Etna* by others. It consists of a large irregular cavity, surrounded by mountains; and the streaks of light are the elevated ridges of ranges of mountains, which seem to converge towards it as to a centre. This is the most variegated and mountainous region of the lunar surface. Fig. 84 is a view of the moon, hastily taken, when in a gibbous phase. The shadows were then comparatively short, and it would require to be engraved on a much more extensive scale than our page admits to show distinctly the elevations and depressions at the boundary between light and darkness. Fig. 85 (Nos. 1 and 2) represent some detached spots near the line which separated the dark and enlightened parts of the moon.

From what has been now stated respecting the lunar mountains, it will evidently appear that there must be a great variety of sublime and picturesque scenery connected with the various landscapes of the moon. If the surface of that orb be adorned with a diversity of colour and with something analogous to the

vegetation of our globe, there must be presented to the view of a spectator in the moon a variety of scenes altogether dissimilar to those which we can contemplate on this earth.

Fig. 84.

The circular plains and mountains will present three or four varieties of prospect, of which we have no examples on our globe. In the first place, a spectator near the middle of the plane will behold his view bounded on every hand by a chain of lofty mountains, at the distance of 5, 10, 15, or 20 miles, according to the diameter of the plain; and as the tops of these mountains are at different elevations, they will exhibit a *variety* of mountain scenery. In the next place, when standing on the top of the central mountain, the whole plain, with its diversified objects, will be open to his view, which will likewise take in all the variety of objects connected with the circular mountain-range which bounds his prospect. A third variety of view will be presented in travelling round the plain, where the various aspects of the central mountain will present, at every stage, a new landscape and a diversity of prospect. Another view, still more extensive, will be obtained by ascending to the summit of the circular range, where the whole plain and its central mountain will be full in view, and a prospect will, at the

Fig. 85. (No. 1.)

Fig. 85. (No. 2.)

same time, be opened of a portion of those regions which lie beyond the *exterior* boundary of the mountains (see Fig. 81.) A diversity of scenery will likewise be presented by the *shadows* of the circular range and the central mountain. When the sun is in the horizon, the whole plain will be enveloped in the shadows of the mountains, even after daylight begins to appear. These shadows will grow shorter and shorter as the sun rises in the heavens; but a space of time equal to one or two of our days will intervene before the body of the sun is seen from the opposite side of the plain, rising above the mountain tops; and a still longer space of time before his direct rays are seen at the opposite extremity. These shadows are continually varying; during the increase of the moon they are thrown in one direction, and during the decrease in a direction exactly opposite; and it is only about the time of full moon that every part of the plain, and the mountains which surround it, are fully enlightened, and the shadows disappear. There must, therefore, be a far greater variety of sublime mountain-scenery, and of picturesque objects connected with it, on the lunar surface, than what is presented to our view in terrestrial landscapes.

*The Lunar Caverns.*—These form a very peculiar and prominent feature of the moon's surface, and are to be seen throughout almost every region; but are most numerous in the south-west part of the moon. Nearly a hundred of them, great and small, may be distinguished in that quarter. They are all nearly of a circular shape, and appear like a very shallow egg-cup. The smaller cavities appear within almost like a hollow cone, with the sides tapering towards the centre; but the larger ones have, for the most part, flat bottoms, from the centre of which there frequently rises a small steep conical hill, which gives them a resemblance to the annular ridges and central mountains above described. In some instances their margins are level with the general surface of the moon, but in most cases they are encircled with a high annular ridge of mountains marked with lofty peaks. Some

of the larger of these cavities contain smaller cavities of the same kind and form, particularly in their sides. The mountainous ridges which surround these cavities reflect the greatest quantity of light; and hence that region of the moon in which they abound appears brighter than any other. From their lying in every possible direction, they appear, at and near the time of full moon, like a number of brilliant streaks or radiations. These radiations appear to converge towards a large brilliant spot surrounded by a faint shade, near the lower part of the moon, which is known by the name of *Tycho*, and which every one who views the full moon, even with a common telescope, may easily distinguish. In regard to their *dimensions*, they are of all sizes, from three miles to fifty miles *in diameter* at the top; and their depth below the general level of the lunar surface varies from one-third of a mile to three miles and a half. Twelve of these cavities, as measured by Schroeter, were found to be above two miles in perpendicular depth. These cavities constitute a *peculiar feature* in the scenery of the moon, and in her physical constitution, which bears scarcely any analogy to what we observe in the physical arrangements of our globe. But, however different such arrangements may appear from what we see around us in the landscapes of the earth, and however unlikely it may at first sight appear that such places should be the abode of intelligent beings, I have no doubt that, in point of beauty, variety, and sublimity, these spacious hollows, with all their assemblage of circular and central mountain-scenery, will exceed in interest and grandeur any individual scene we can contemplate on our globe. We have only to conceive that such places are diversified and adorned with all the vegetable scenery which we reckon beautiful and picturesque in a terrestrial landscape, and with objects which are calculated to reflect with brilliancy the solar rays, in order to give such an idea of the grandeur of the scene. And that the objects connected with these hollows are formed of substances fitted to reflect the rays of the sun with peculiar lustre, appears from the brilliancy which most of them exhibit when either partially or wholly enlightened; presenting to view, especially at full moon, the most luminous portions of the lunar surface, so that former astronomers were led to compare them to rocks of diamond.

*Whether there be any evidence of Volcanoes in the Moon.*—From a consideration of the broken and irregular ground, and the deep caverns which appear in different parts of the moon's surface, several astronomers were led to conjecture that such irregularities were of volcanic origin. These conjectures were supposed to be confirmed by the appearance of certain luminous points, which were occasionally seen on the dark part of the moon. During the annular eclipse of the sun on the 24th of June, 1778, Don Ulloa perceived, near the north-west limb of the moon, a bright white spot, which he imagined to be the light of the sun shining through an opening in the moon. This phenomenon continued about a minute and a quarter, and was noticed by three different observers. Beccaria observed a similar spot in 1772. M. Bode, of Berlin, M. de Villeneuve, M. Nouet, Captain Kater, and several others, at different times observed similar phenomena, some of which had the appearance of a small nebula, or a star of the sixth magnitude, upon the dark part of the lunar disk. Sir W. Herschel, in 1787, observed similar phenomena, which he ascribes to the eruption of volcanoes. The following is an extract from his account of those phenomena: "April 19, 1787, 10*h*. 36*m*. I perceive three volcanoes in different places of the dark part of the new moon. Two of them are already nearly extinct, or otherwise in a state of going to break out; the third shows an eruption of fire or luminous matter. The distance of the crater from the northern limb of the moon is 3′ 57″; its light is much brighter than the nucleus of the comet which M. Mechain discovered at Paris on the 10th of this month." "April 20, 10*h*. The volcano burns with greater violence than last night; its diameter cannot be less than three seconds; and hence the shining or burning matter must be above three miles in diameter. The appearance resembles a small piece of burning charcoal when it is covered by a very thin coat of white ashes, and it has a degree of brightness about as strong as that with which such a coal would be seen to glow in faint daylight."

Such are some of the phenomena from which it has been concluded that volcanoes exist in the moon. That such appearances indicate the existence of fire or some species of luminosity on the lunar surface, is readily admitted; but they by no means prove that any thing similar to terrestrial volcanoes exist in that orb. We err egregriously when we suppose that the arrangements of other worlds must be similar to those on our globe, especially when we perceive the surface of the moon arranged in a manner so very different from that of the earth. We have no right to conclude that burning mountains abound in the moon because these are the only large streams of fire that occasionally burst forth from certain points on our globe. For there are many other causes of which we are ignorant, and which may be peculiar to the moon, which may produce the occasional gleams or illumi-

nations to which we allude. The conflagration of a large forest, such as happened a few years ago at Miramichi, the blazing of large tracts of burning heath, the illumination of a large town, or the conflagration of such a city as Moscow, would, in all probability, present to a spectator in the moon luminous specks such as those which astronomers have observed on the dark portion of the lunar orb. Such luminosities in the moon may possibly be of a phosphoric nature, or a mere display of some brilliant artificial scenery by the inhabitants of that planet. Schroeter is of opinion that most of these appearances are to be ascribed to the light reflected from the earth to the dark part of the moon's disk, which returns it from the tops of the mountains under various angles, and with different degrees of brightness; and from various observations I have made on the dark portion of the moon, when about two or three days old, and from the degree of brightness with which some of the small spots have frequently appeared, I am disposed to consider this opinion as highly probable.

The existence of volcanoes on our globe is scarcely to be considered as a part of its original constitution. Such appalling and destructive agents appear altogether inconsistent with the state of an innocent being formed after the Divine image; and, therefore, we have no reason to believe that they existed in the primitive age of the world, while man remained in his paradisiacal state, but began to operate only after the period of the universal deluge, when the primitive constitution of our globe was altered and deranged, and when earthquakes, storms, and tempests began, at the same time, to exert their destructive energies. They are thus to be considered as an evidence or indication that man is no longer in a state of moral perfection and that his habitation now corresponds with his character as a sinner. To suppose, therefore, that such destructive agents exist in the moon, would be virtually to admit that the inhabitants of that planet are in the same depraved condition as the inhabitants of this world. The same thing may be said with regard to a pretended discovery which was announced some years ago, that "there are *fortifications* in the moon;" for, if such objects really existed, it would be a plain proof that the inhabitants were engaged in wars and contentions, and animated with the same diabolical principles of pride, ambition, and revenge, which have ravaged our globe and demoralized its inhabitants.

*Whether there be Seas in the Moon* is a question which has engaged the attention of astronomers, and which demands a few remarks. When we view the moon through a good telescope, we perceive a number of large dark spots, of different dimensions, some of which are visible to the naked eye. These spots, in the early observations of the moon with telescopes, were generally supposed to be large collections of water similar to our seas, and the names given them by Hevelius, such as *Mare Crisium*, *Mare Imbrium*, &c., are founded on this opinion. The general smoothness of these obscure regions, and the consideration that water reflects less light than the land, induced some astronomers to draw this conclusion. But there appears no solid ground for entertaining such an opinion; for, in the first place, when these dark spots are viewed with good telescopes, they are found to contain numbers of cavities, whose shadows are distinctly perceived falling within them, which can never happen in a sea or smooth liquid body; and besides, several insulated mountains, whose shadows are quite perceptible, are found here and there in these supposed seas. In the next place, when the boundary of light and darkness passes through these spots, it is not exactly a straight line or a regular curve, as it ought to be were those parts perfectly level like a sheet of water, but appears slightly jagged or uneven. I have inspected these spots hundreds of times, with powers of 150, 180, and 230 times, and in every instance, and in every stage of the moon's increase and decrease, gentle elevations and depressions were seen, similar to the wavings or inequalities which are perceived upon a plain or country generally level. There are scarcely any parts of these spots in which slight elevations may not be seen. In many of them the light and shade, indicating the inequality of surface, are quite perceptible; and in certain parts ridges nearly parallel, of slight elevation, with interjacent plains, are distinctly visible. These dark spots, therefore, must be considered as *extensive plains* diversified with gentle elevations and depressions, and consisting of substances calculated to reflect the light of the sun with a *less degree of intensity* than the other parts of the lunar surface. These plains are of different dimensions, from 40 or 50 to 700 miles in extent, and they occupy more than one-third of that hemisphere of the moon which is seen from the earth, and, consequently, will contain nearly three millions of square miles. As the moon, therefore, is diversified with mountains and cavities of forms altogether different from those of our globe, so the plains upon the surface of that orb are far more varied and extensive than the generality of plains which are found on the surface of the earth. It is a globe diversified with an immense variety of mountain scenery, and, at the same time, abounding with plains and valleys of vast extent. But there appear to be no seas, oceans, or any *large* collections of

water, though it is possible that small lakes or rivers may exist on certain parts of its surface. As we see only one side of the moon from the earth, we cannot tell what objects or arrangements may exist on its opposite hemisphere, though it is probable that that hemisphere does not differ *materially* in its scenery and arrangements from those which are seen on the side which is turned towards the earth.

*Atmosphere of the Moon.*—Whether the moon has an atmosphere, or body of air similar to that which surrounds the earth, has been a subject of dispute among astronomers. On the one side, the existence of such an atmosphere is denied, because the stars which disappear behind the body of the moon retain their full lustre till they seem to touch its very edge, and then they vanish in a moment; which phenomenon, it is supposed, would not happen if the moon were encompassed with an atmosphere. On the other hand, it has been maintained that the phenomena frequently attending eclipses of the sun furnish arguments for the existence of a lunar atmosphere. It has been observed on different occasions that the moon in a solar eclipse was surrounded with a luminous ring, which was most brilliant on the side nearest the moon; that the sharp horns of the solar crescent have been seen blunted at their extremities during total darkness; that, preceding the emersion, a long narrow streak of dusky red light has been seen to colour the western limb of the moon; and that the circular figure of Jupiter, Saturn, and the fixed stars has been seen changed into an elliptical one when they approached either the dark or the enlightened limb of the moon; all which circumstances are considered as indications of a lunar atmosphere. The celebrated M. Schroeter, of Lilienthal, made numerous observations in order to determine this question, and many respectable astronomers are of opinion that his observations clearly prove the existence of an atmosphere around the moon. He discovered near the moon's cusps a faint gray light of a pyramidal form, extending from both cusps into the dark hemisphere, which, being the moon's twilight, must necessarily arise from its atmosphere. It would be too tedious to detail all the observations of Schroeter on this point; but the following are the general conclusions: "That the inferior or more dense part of the moon's atmosphere is not more than 1500 English feet high; and that the height of the atmosphere where it could affect the brightness of a fixed star, or inflect the solar rays, does not exceed 5742 feet," or little more than an English mile. A fixed star will pass over this space in less than two seconds of time; and if it emerge at a part of the moon's limb where there is a ridge of mountains, scarcely any obscuration can be perceptible.

On the whole, it appears most probable that the moon is surrounded with a fluid which serves the purpose of an atmosphere, although this atmosphere, as to its nature, composition, and refractive power, may be very different from the atmosphere which surrounds the earth. It forms no proof that the moon or any of the planets is destitute of an atmosphere because its constitution, its density, and its power of refracting the rays of light are different from ours. An atmosphere may surround a planetary body, and yet its parts be so fine and transparent that the rays of light from a star or any other body may pass through it without being in the least obscured or changing their direction. In our reasonings on this subject we too frequently proceed on the false principle that every thing connected with other worlds must bear a resemblance to those on the earth. But as we have seen that the surface of the moon, in respect to its mountains, caverns, and plains, is very differently arranged from what appears on the landscape of our globe, so we have every reason to conclude that the atmosphere with which that orb may be surrounded is materially different in its constitution and properties from that body of air in which we move and breathe; and it is highly probable, from the diversity of arrangements which exists throughout the planetary system, that the atmospheres of all the planets are variously constructed, and have properties different from each other. Whatever may be the nature of the moon's atmosphere, it is evident that nothing similar to *clouds* exists in it, otherwise they would be quite perceptible by the telescope; and hence we may conclude that neither hail, snow, rain, nor tempests disturb its serenity; for all the parts uniformly present a clear, calm, and serene aspect, as if its inhabitants enjoyed a perpetual spring.

*Magnitude of the Moon.*—The distance of the moon from the earth is determined from its horizontal parallax; and this distance, compared with its *apparent* angular diameter, gives its *real* or linear diameter. The mean horizontal parallax is fifty-seven minutes, thirty-four seconds, and the mean apparent diameter thirty-one minutes, twenty-six seconds. From these *data* it is found that the real diameter of the moon is 2180 miles, which is little more than the one fourth of the diameter of the earth. The real magnitude of the moon, therefore, is only about one forty-ninth part of that of the earth. This is found by dividing the cube of the earth's diameter by the cube of the moon's, and the quotient will express the number of times that the bulk of the earth exceeds that of the moon; for the real bulk of globes is in proportion to the cubes

of their diameters. Although the apparent size of the moon appears equal to that of the sun, yet the difference of their real bulk is very great, for it would require more than *sixty-three millions* of globes of the size of the moon to form a globe equal in magnitude to that of the sun. Its surface, notwithstanding, contains a very considerable area, comprising nearly 15,000,000 of square miles, or about one third of the habitable parts of our globe; and were it as densely peopled as England, it would contain a population amounting to *four thousand two hundred millions*, which is more than five times the population of the earth; so that the moon, although it ranks among the smallest of the celestial bodies, may contain a population of intelligent beings far more numerous, and perhaps far more elevated in the scale of intellect, than the inhabitants of our globe.

*Whether it may be possible to discover the inhabitants of the moon* is a question which has been sometimes agitated. To such a question I have no hesitation in replying, that it is highly improbable that we shall ever obtain a direct view of any living beings connected with the moon by means of any telescopes which it is in the power of man to construct. The greatest magnifying power which has ever been applied, *with distinctness*, to the moon, does not much exceed a thousand times; that is, makes the objects in the moon appear a thousand times larger and nearer to the naked eye. But even a power of a thousand times represents the objects on the lunar surface at a distance of 240 miles, at which distance no living beings, although they were nearly of the size of a kraken, could be perceived. Even although we could apply a power of ten thousand times, lunar objects would still appear 24 miles distant; and at such a distance no animal, even of the size of an elephant or a whale, could be discerned. Besides, we ought to consider that we have only a *bird's-eye view* of the objects on the moon; and, consequently, supposing any beings resembling man to exist on that orb, we could only perceive the diameter of their heads, as an aeronaut does when he surveys the crowds beneath him from an elevated balloon. Nay, though it were possible to construct a telescope with a power of one hundred thousand times, which would cause the moon to appear as if only two and a half miles distant, it is doubtful if, even with such an instrument, living beings could be perceived. We ought also to consider that nature has set certain limits to the magnifying power of telescopes; for, although we could apply such powers as now stated to any telescope, the vapours and undulations of the atmosphere, and the diurnal motion of the earth, would interpose a barrier to distinct vision, and as the quantity of light is diminished in proportion to the magnifying power, the loss of light in such high powers would prevent the distinct perception of any object.

But although we can never hope to *see* any of the inhabitants of the moon by any instrument constructed by human ingenuity, yet we may be able *to trace the operations* of sentient or intelligent beings, or those *effects* which indicate the agency of living beings. A navigator who approaches within a certain distance of a small island, although he perceives no human beings upon it, can judge with certainty that it is inhabited if he perceive human habitations, villages, corn-fields, or traces of cultivation. In like manner, if we could perceive changes or operations in the moon which could be traced to the agency of intelligent beings, we should then obtain demonstrative evidence that such beings exist on that planet; and I have no doubt that it is possible to trace such operations. A telescope which magnifies 1200 times will enable us to perceive, *as a visible point* on the surface of the moon, an object whose diameter is only about 100 yards or 300 feet. Such an object is not larger than many of our public edifices; and, therefore, were any such edifices rearing in the moon, or were a town or city extending its boundaries, or were operations of this description carrying on in a district where no such edifices had previously been erected, such objects and operations might probably be detected by a minute inspection. Were a multitude of living creatures moving from place to place in a body, or were they encamping in an extensive plain like a large army, or like a tribe of Arabs in the desert, and afterward removing, it is possible that such movements might be traced by the difference of shade or colour which such movements would produce. In order to detect such minute objects and operations, it would be requisite that the surface of the moon should be distributed among at least a hundred astronomers, each having a spot or two allotted him as the object of his more particular investigation, and that the observations be continued for a period of at least thirty or forty years, during which time certain changes would probably be perceived, arising either from physical causes or from the operations of living agents. But although no such changes should ever be detected, it would form no proof that the moon is destitute of inhabitants; for, in other worlds, intelligent beings may probably enjoy all the happiness congenial to their natures without those edifices or artificial accommodations which are requisite for man in this terrestrial abode. In reference to the subject under consideration

Dr. Olbers is fully of opinion "that the moon is inhabited by rational creatures, and that its surface is more or less covered with a vegetation not very dissimilar to that of our own earth." Gruithuisen maintains that he has discovered, by means of his large achromatic telescope, "great artificial works in the moon, erected by the lunarians." And lately, another foreign observer maintains, from actual observation, "that great edifices do exist in the moon." I am of opinion that all such announcements are premature and uncertain. Without calling in question the accuracy of the descriptions published by these astronomers, there is some reason to suspect that what they have taken for "edifices" and "artifical works" are only small portions of natural scenery, of which an immense variety, in every shape, is to be found on the surface of the moon. Future and more minute observations may, however, enable us to form a definite opinion on this subject.*

It has sometimes been a subject of speculation whether it might be possible, by any symbols, to correspond with the inhabitants of the moon. "Gruithuisen, in a conversation with the great continental astronomer Gauss, after describing the regular figures he had discovered in the moon, spoke of the possibility of a correspondence with the lunar inhabitants. He brought to Gauss' recollection the idea he had communicated many years ago to Zimmerman. Gauss answered, that the plan of erecting a geometrical figure on the plains of Siberia corresponded with his opinion, because, according to his view, a correspondence with the inhabitants of the moon could only be begun by means of such mathematical contemplations and ideas which we and they must have in common."† Were the inhabitants of the moon to recognize such a figure, erected on an immense scale, as a signal of correspondence, they might perhaps erect a similar one in reply. But it is questionable whether the intention of such a signal would be recognized; and our terrestrial sovereigns are too much engaged in plunder and warfare to think of spending their revenues in so costly an experiment; and, therefore, it is likely that, for ages to come, we shall remain in ignorance of the genius of the lunar inhabitants. Schemes, however, far more foolish and preposterous than the above have been contrived and acted upon in every age of the world. The millions which are now wasting in the pursuits of mad ambition and destructive warfare might, with far greater propriety, be expended in constructing a large triangle or ellipsis, of many miles in extent, in Siberia or any other country, which might at the same time accommodate thousands of inhabitants who are now roaming the desarts like the beasts of the forest.

Whatever may be the arrangements of the the moon or the genius of its inhabitants, we know that it forms a most beautiful and bene-

* A short time ago a *hoax* was attempted to be played off on the public in relation to this subject. An article entitled "Wonderful Discoveries in the Moon, by Sir John Herschel," was copied into most of the American, French, and British newspapers and other periodicals, and was likewise published in a separate pamphlet. It is not a little astonishing how easily the public is gulled by such extravagant descriptions as were contained in this pamphlet, and it shows the *ignorance* which still prevails among the great mass of the community in every country in relation to astronomy and optics, that such pretended discoveries should have been listened to even for a moment. For even some editors of newspapers treated the affair in a grave manner, and only expressed their *doubts* on the subject, plainly indicating that they had far less knowledge of the science of astronomy than many schoolboys now acquire. The title of the pamphlet was sufficient to convince any man of common understanding, who directed his attention for a moment to the subject, that the whole was a piece of deception; for it stated that "the object-glass weighed *seven tons*," and had "a magnifying power of 42,000 times." Now, supposing such a power had been used, the objects on the surface of the moon would still have appeared more than five miles and two-thirds distant; and how could an animal, even of the largest size, be seen at such a distance? Yet the writer of the pamphlet declares that animals such as sleep, and cranes, and small birds were not only distinguished, but the shape and colour of their horns, eyes, beard, and the difference of sexes, were perceived. To perceive such objects it was requisite that they should have been brought within six yards instead of six miles. The author might have rendered his description more consistent by putting a power of 300,000 times upon his imaginary telescope, since he had every power at his command, so as to have brought the objects, at least, within the distance of a mile. The author of this deception, I understand, is a young man in the city of New York, who makes some pretensions to scientific acquirements, and he may perhaps be disposed to congratulate himself on the success of his experiment on the public. But it ought to be remembered that all such attempts to deceive are violations of the laws of the Creator, who is the "God of truth," and who requires "truth in the inward parts;" and, therefore, they who wilfully and deliberately contrive such impositions ought to be ranked in the class of liars and deceivers. The "Law of *Truth*" ought never for a moment to be sported with. On the universal observance of this law depend the happiness of the whole intelligent system and the foundations of the throne of the Eternal. The greatest part of the evils which have afflicted our world have risen from a violation of this law, and were it to be *universally* violated, the inhabitants of all worlds would be thrown into a state of confusion and misery, and creation transformed into a chaos. Besides, the propagation of such deceptions is evidently injurious to the interests of science. For when untutored minds and the mass of the community detect such impositions, they are apt to call in question the *real* discoveries of science, as if they were only attempts to impose on their credulity It is to be hoped that the author of the deception to which I have adverted, as be advances in years and in wisdom, will perceive the folly and the immorality of such conduct.

† Edinburgh New Philosophical Journal for October, 1826, p. 390.

ficial appendage to our globe. When the sun has descended below the western horizon, the moon lights up her lamp in the azure firmament, and diffuses a mild radiance over the landscape of the world. She pours her lustre on spacious cities and lofty mountains, glittering on the ocean, the lakes, and rivers, and opening a prospect wide as the eye can reach, which would otherwise be involved in the deepest gloom. As the son of Sirach has observed, "She is the beauty of heaven, the glory of the stars, an ornament giving light in the high places of the Lord." She cheers the traveller in his journeys, the shepherd while tending his fleecy charge, and the mariner while conducting his vessel at midnight through the boisterous ocean. She returns to us, during night, a portion of the solar light which we had lost, and diffuses a brilliancy far superior to that which we derive from all the stars of heaven. If we intend to prosecute our journeys after the sun has left our hemisphere, the moon, in her increase, serves as a magnificent lamp to guide our footsteps. If we wish to commence our progress at an early hour in the morning, the moon, in her decrease, diffuses a mild radiance in the east, and enables us to anticipate the dawn; and if we choose to defer our journey till the period of full moon, this celestial lamp enables us to enjoy, as it were, an uninterrupted day of twenty-four hours long. By this means we can either avoid the burning heats of summer, or despatch such business as may be inexpedient during the light of day. While the apparent revolution of the sun marks out the year and the course of the seasons, the revolution of the moon round the heavens marks out our months; and, by regularly changing its figure at the four quarters of its course, subdivides the month into periods of weeks; and thus exhibits to all the nations of the earth a "watchlight" or signal, which every seven days presents a form entirely new, for marking out the shorter periods of duration. By its nearness to the earth, and the consequent increase of its gravitating power, it produces currents in the atmosphere, which direct the course of the winds and purify the aerial fluid from noxious exhalations; it raises the waters of the ocean, and penetrates the regular returns of ebb and flow, by which the liquid element is preserved from filth and putrefaction. It extends its sway even over the human frame, and our health and disorders are sometimes partially dependent on its influence. Even its eclipses, and those it produces of the sun, are not without their use. They tend to arouse mankind to the study of astronomy and the wonders of the firmament; they serve to confirm the deductions of chronology, to direct the navigator, and to settle the geographical positions of towns and countries; they assist the astronomer in his celestial investigations, and exhibit an agreeable variety of phenomena in the scenery of the heavens. In short, there are terrestrial scenes presented in moonlight, which, in point of solemnity, grandeur, and picturesque beauty, far surpass in interest, to a poetic imagination, all the brilliancy and splendours of noonday. Hence, in all ages, a moonlight scene has been regarded, by all ranks of men, with feelings of joy and sentiments of admiration. The following description of Homer, translated into English verse by Mr. Pope, has been esteemed one of the finest night-pieces in poetry.

"Behold the moon, refulgent lamp of night,
O'er heaven's clear azure spread her sacred light,
When not a breath disturbs the deep serene,
And not a cloud o'ercasts the solemn scene;
Around her throne the vivid planets roll,
And stars unnumbered gild the glowing pole;
O'er the dark trees a yellower verdure shed,
And tip with silver every mountain's head;
Then shine the vales; the rocks in prospect rise;
A flood of glory bursts from all the skies.
The conscious swains, rejoicing in the sight,
Eye the blue vault, and bless the useful light."

Without the light of the moon, the inhabitants of the polar regions would be for weeks and months immersed in darkness. But the moon, like a kindly visitant, returns at short intervals in the absence of the sun, and cheers them with her beams for days and weeks together. So that, in this nocturnal luminary, as in all the other arrangements of nature, we behold a display of the paternal care and beneficence of that Almighty Being who ordained "the moon and stars to rule the night," as an evidence of his superabundant goodness, and of "his mercy, which endureth for ever."

### II. ON THE SATELLITES OF JUPITER.

There are four moons or satellites attending the planet Jupiter, which revolve around it from west to east, according to the order of the signs, or in the same direction as the moon revolves round the earth and the planets round the sun. They are placed at different distances from the centre of Jupiter; they revolve round it in different periods of time, and they accompany the planet in its twelve years' revolution round the sun, without deviating in the least in their distances from the planet, as the more immediate centre of their motions. These bodies were discovered by Galileo, who first applied the telescope to celestial observations. Three of them were first seen on the night of the 7th of January, 1610, and were at first supposed to be telescopic stars; but by the observations of three or four subsequent evenings, he discovered them to be attendants on the planet Jupiter

On the 13th of the same month he saw the fourth satellite, and continued his observations till March 2, when he sent his drawings of them, and an account of his observations, to his patron, *Cosmo Medici*, Great Duke of Tuscany, in honour of whom he called them the *Mediceean stars*. This discovery soon excited the attention of astronomers, and every one hastened with eagerness to view the new celestial wonders. The senators of Venice, who were eminent for their learning, invited Galileo to come to the tower of St. Mark, and in their presence make a trial of his new instruments. He complied with their request, and in a fine night, neither cold nor cloudy, showed them with his instrument the new phenomena which had excited attention; the satellites of Jupiter, the crescent of Venus, the triple appearance of Saturn, and the inequalities on the surface of the moon, which many of the learned refused to admit, because they overthrew the system of the schools and the philosophical notions which had previously prevailed. At this conference with the Venetian senators Galileo demonstrated the truth of the Copernican system, and showed how all his discoveries had a tendency to prove that the earth is a moving body, and that the sun is the centre of the planetary motions.

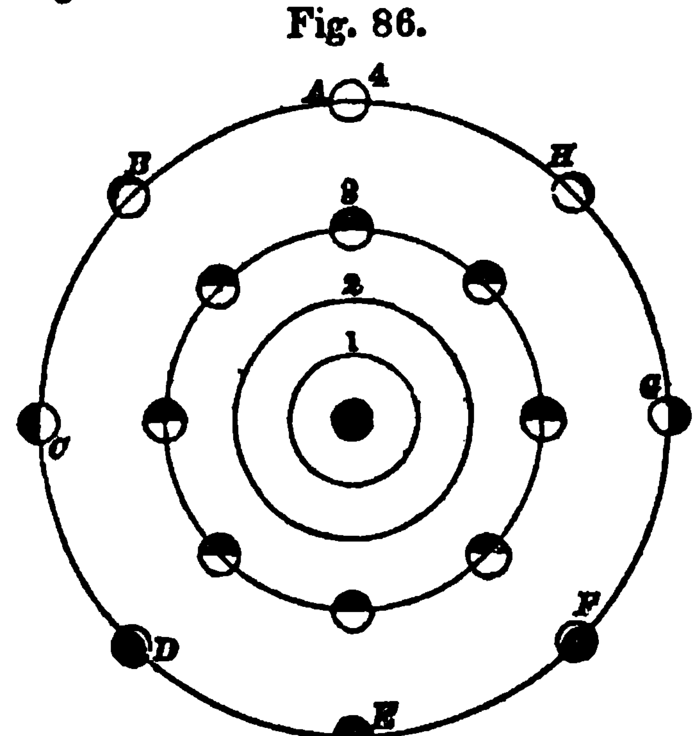
The following are the respective distances of the satellites of Jupiter, in round numbers, and the periodic times in which they revolve around that planet. The mean distance of the first satellite from the centre of Jupiter is 260,000 miles, or somewhat more than the distance of the moon from the earth; and it revolves around the planet in 1 day, 18 hours, 27½ minutes. The second satellite is distant 420,000 miles, and finishes its revolution in 3 days, 13 hours, 13¾ minutes. The third is distant 670,000 miles, and performs its revolution in 7 days, 3 hours, 42½ minutes. The fourth satellite is distant 1,180,000 miles, or more than four times the distance of the first, and requires 16 days, 16 hours, and 32 minutes to complete its revolution. These satellites suffer numerous eclipses in passing through the shadow of Jupiter, as our moon is eclipsed in passing through the shadow of the earth. But as their orbits are very little inclined to the orbit of Jupiter, their eclipses are much more frequent than those of our moon. The first three satellites are eclipsed every time they are in opposition to the sun. The first satellite is in opposition once in 42½ hours, and, consequently, suffers an eclipse about eighteen times every month. The second suffers eight or nine eclipses, and the third about four eclipses every month. But the fourth satellite frequently passes through its opposition without being involved in the shadow of Jupiter, and, consequently, its eclipses are less frequent than those of the other three, only a few of them happening in the course of a year. As those satellites are opaque globes like our moon—when they are in their inferior conjunction, or in a line between Jupiter and the sun—their bodies are interposed between the sun and certain parts of the disk of the planet, so as to cause an eclipse of the sun to those places over which their shadow passes. These eclipses, or the shadows of the satellites passing across the body of Jupiter, are perceived by powerful telescopes. Sometimes the satellites themselves may be seen crossing the disk like luminous spots; and sometimes the body of the planet interposes between our eye and the satellites, when they are said to suffer an *occultation*. It has been ascertained, by the calculations and investigations of La Place, *that the whole number of these moons can never be eclipsed at the same time*, and that scarcely ever more than two of them can be eclipsed at once.

The following diagram (Fig. 86,) exhibits the system of Jupiter's satellites nearly in the proportion of their distances from the planet. The small circles on the orbit of the third satellite represent the enlightened side of the satellites turned towards the sun, and the dark side in an opposite direction. The enlightened side of every satellite is always very nearly turned towards the earth; but in their revolutions round Jupiter they present to that planet all the phases of the moon, as represented in the figures marked on the orbit of the fourth satellite. In the direction *A*, when in opposition to the sun, they appear like *full moons;* in the direction *B* they assume a *gibbous* phase; at *C* they appear like a *half moon;* at *D* like a *crescent;* at *E*, the dark side being turned towards the planet, the satellite becomes invisible; at *F*, *G*, and *H*, it again successively appears under a crescent, a half moon, and a gibbous phase. In the direction *A* the satellites are in opposition to the sun, as seen from Jupiter, at which time they pass through his shadow, and are eclipsed for the space of more than two hours, with the exception of the fourth, which sometimes passes the point of its opposition without falling into the shadow. At *E* the shadow of the satellite passes across the disk of Jupiter, producing a solar eclipse to all those regions on his surface over which the shadow moves.

These satellites, when viewed from the earth, do not appear to revolve round Jupiter in the manner here represented, but seem to oscillate backward and forward nearly in a straight line. This is owing to our being nearly on a level with the plane of their orbits. When the earth is in one of the geocentric nodes of a satellite, the plane of its orbit

passes through our eye, and therefore it appears to be a straight line, as *a b*, (Fig. 87,) so that, in passing the half of its orbit which is most distant from the earth, it first seems to move from *b* to *c*, when it is hidden for some time by the planet, and then from *d* to *a*, the point of its greatest elongation; after which it seems to return again in the same line, passing between us and the disk of the planet, till it arrives at its greatest elongation at *b*. In every other situation of the earth, the orbit of a satellite appears as an ellipsis more or less oblong, as represented in Fig. 88. When it passes through its superior semicircle, or that which is more distant from the earth than Jupiter is, as *e*, *f*, *g*, its motion is *direct*, or according to the order of the signs; when it is in its inferior semicircle, nearer to us than Jupiter, as *h*, *i*, *k*, its apparent motion is in the opposite direction, or *retrograde*. Hence these satellites, as seen through a telescope, appear nearly in a straight line from the body of Jupiter, as represented in Fig. 89.

Fig. 86.



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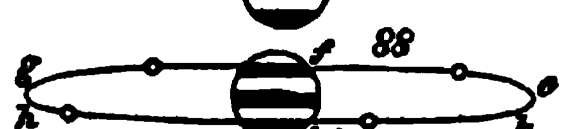


89

*Magnitude of the Satellites.*—These bodies, though invisible to the naked eye, are nevertheless of a considerable size. The following are their diameters in miles, as stated by Struve. The first satellite is 2508 miles in diameter, which is considerably larger than our moon. The second is 2068 miles in diameter, or about the size of the moon. The third is 3377 miles in diameter, which is more than seven times the bulk of the moon. The fourth is 2890 miles in diameter, or about three times the bulk of the moon; so that the whole of Jupiter's satellites are equal to nearly thirteen of our moons.* The superficial contents of the first satellite is 19,760,865 square miles; of the second, 13,435,442; of the third, 35,827,211; and of the fourth, 26,238,957 square miles. The number of square miles on all the satellites is, therefore, 95,262,475, or more than ninety-five millions of square miles, which is about double the quantity of surface on all the habitable parts of our globe. At the rate of 280 inhabitants to every square mile, these satellites would, therefore, be capable of containing a population of 26,673 *millions*, which is thirty-three times greater than the population of the earth.

The satellites of Jupiter may be seen with a telescope magnifying about thirty times; but in order to perceive their eclipses with advantage, a power of one hundred or one hundred and fifty times is requisite. When the brilliancy of the satellites is examined at different times, it appears to undergo a considerable change. By comparing the mutual positions of the satellites with the times when they acquire their maximum of light, Sir W. Herschel concluded that, like the moon, they all turned round their axis in the same time that they performed their revolution round Jupiter. The same conclusion had been deduced by former astronomers in reference to the fourth satellite. This satellite was sometimes observed to take but half the usual time in its entrance on the disk of Jupiter or its exit from it, which was supposed to be owing to its having a dark spot upon it that covered half its diameter; and, by observing the period of its variations, it was concluded that it had a rotation round its axis. These circumstances form a presumptive proof that the surface of these satellites, like our moon, are diversified with objects of different descriptions, and with varieties of light and shade. Cassini suspected the first satellite to have an atmosphere, because the shadow of it could not be seen, when he was sure it should have been, upon the disk of Jupiter, if it had not been shortened by its atmosphere, as is the case in respect to the shadow of the earth in lunar eclipses.

From what has been stated respecting the motions, magnitudes, and eclipses of these satellites, it is evident they will present a most

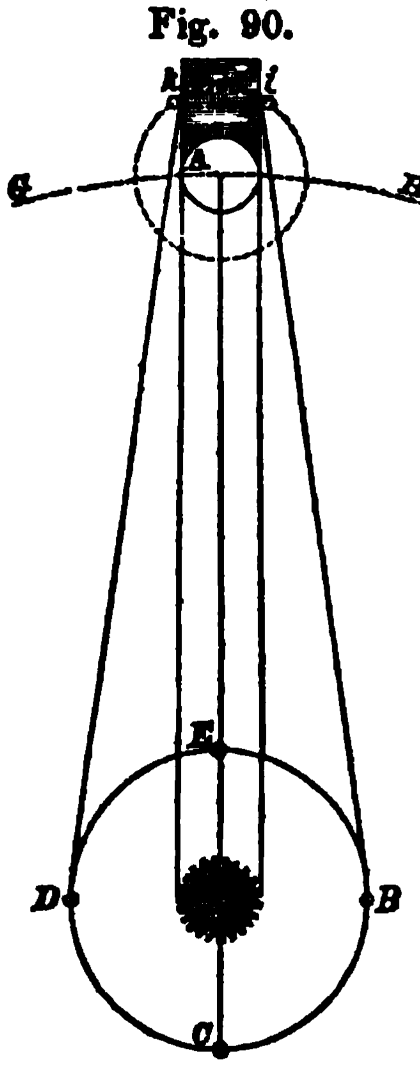
* Former astronomers reckoned the bulk of the satellites larger than the dimensions here stated. Cassini and Maraldi reckoned the diameter of the third satellite to be one-eighteenth of the diameter of Jupiter, and, consequently, nearly 5000 miles in diameter; and the first and second to be one-twentieth of Jupiter's diameter, or about 4450 miles; which estimation would make the magnitudes of these bodies much larger than stated by Struve.

diversified and sublime scenery in the firmament of Jupiter. The first satellite moves along a circumference of 1,633,632 miles in the space of 42½ hours, at the rate of 38,440 miles an hour, which is a motion sixteen times more rapid than that of the moon in its circuit round the earth. During this short period it presents to Jupiter all the appearances of a new moon, crescent, half moon, gibbous phase, and full moon, both in the increase and decrease; so that, in the course of twenty-one hours, it passes through all the phases which our moon exhibits to us; besides suffering an eclipse in passing through the shadow of the planet, and producing either a partial or total eclipse of the sun to certain regions of Jupiter on which its shadow falls. The rapidity of its motion through the heavens will also be very striking; as it will move through the whole hemisphere of the heavens in the course of twenty-one hours, besides its daily apparent motion, in consequence of the diurnal rotation of Jupiter. The other three satellites will exhibit similar phenomena, but in different periods of time. Sometimes two or three of these moons, and sometimes all the four, will be seen shining in the firmament at the same time; one like a crescent, one like a half moon, and another in all its splendour as a full enlightened hemisphere; one entering into an eclipse, another emerging from it; one interposing between the planet and the sun, and for a short time intercepting his rays; one advancing from the eastern horizon, and another setting in the west; one satellite causing the shadows of objects on Jupiter to be thrown in one direction, and another satellite causing them to be projected in another, or in an opposite direction; while the rapid motions of these bodies among the fixed stars will be strikingly perceptible. Eclipses of the satellites and of the sun will be almost an everyday phenomenon, and occultations of the fixed stars will be so frequent and regular as to serve as an accurate measure of time.

The eclipses of Jupiter's satellites afford signals of considerable use for determining the longitude of places on the earth. For this purpose tables of these eclipses, and of the times at which the satellites pass across the disk of Jupiter or behind his body, are calculated and inserted in the nautical and other almanacs. These tables are adapted to the meridian of the Royal Observatory at Greenwich; and by a proper use of them, in connexion with observations of the eclipses, the true meridian, or the distance of a place east or west from Greenwich, may be ascertained. For example: suppose, on the 27th of December, 1837, the immersion of Jupiter's first satellite be observed to happen, in an unknown meridian, at 15 hours, 23 minutes, 10 seconds, I find by the tables that this immersion will happen at Greenwich at 13 hours, 34 minutes, 50 seconds of the same day. The difference of the time is 1 hour, 48 minutes, 20 seconds, which, being converted into degrees of the equator (allowing 15 degrees for an hour,) will make 27 degrees, 5 minutes, which is the longitude of the place of observation. This longitude is *east* of Greenwich, because the time of observation was *in advance* of the time at the British observatory. Had the time of observation been behind that of Greenwich, for example, at 13 hours, 4 minutes, 50 seconds, the place must then have been 7½ degrees west of the Royal Observatory. *Before* Jupiter's opposition to the sun, or when he passes the meridian in the morning, the shadow is situated to the *west* of the planet, and the *immersions* happen on that side; but *after* the opposition the *emersions* happen to the *east*. These eclipses cannot be observed with advantage unless Jupiter be eight degrees *above*, and the sun at least eight degrees *below* the horizon.

The eclipses of Jupiter's moons first suggested the idea of *the motion of light*. As the orbit of the earth is concentric with that of Jupiter, the mutual distance of these two bodies is continually varying. In the following figure let $S$ represent the sun; $B$, $C$, $D$, $E$, the orbit of the earth; and $G$, $H$, a portion of the orbit of Jupiter. It is evident that when the earth is at $E$ and Jupiter at $A$, the earth will be the semidiameter of its orbit nearer Jupiter than when it is at $B$ or $D$; and when at $C$ it will be the whole diameter of its orbit, or 190,000,000 of miles further from Jupiter than when it is at $E$. Now if light were instantaneous, the satellite $i$, to a spectator at $B$, would appear to enter into Jupiter's shadow, $k$ $i$, at the same moment of time as to another spectator at $E$. But, from numerous observations, it was found, that when the earth was at $E$, the immersion of the satellite into the shadow happened sooner by eight minutes and a quarter than when the earth was at $B$, and sixteen minutes and a half sooner than when the earth was at

Fig. 90.



C. It was therefore concluded that light is not instantaneous, but requires a certain space of time to pass from one region of the universe to another, and that the time it takes in passing from the sun to the earth, or across the semidiameter of the earth's orbit, is eight minutes and a quarter, or at the rate of 192,000 miles every second, which is more than ten hundred thousand times swifter than a cannon ball the moment it is projected from the mouth of the cannon; and therefore it is the swiftest movement with which we are acquainted in nature. It follows that, if the sun was annihilated, we should see him for eight minutes afterward; and if he were again created, it would be eight minutes before his light would be perceived. The motion of light deduced from the eclipses of Jupiter's satellites has been confirmed by Dr. Bradley's discovery of the *aberration of light* produced by the annual motion of the earth, from which it appears that the light from the fixed stars moves with about the same velocity as the light of the sun.

### III. ON THE SATELLITES OF SATURN.

Saturn is surrounded with no less than seven satellites, which revolve around him, at different distances, in a manner similar to those of Jupiter. As they are more difficult to be perceived than the satellites of Jupiter, owing to the great distance of Saturn from the earth, none of them were discovered till the telescope was considerably improved; and more than a century intervened after the first five satellites till the sixth and seventh were detected. As was to be supposed, the larger satellites were first discovered. In the year 1665, about forty-five years after the invention of the telescope, M. Huygens, a celebrated Dutch mathematician and astronomer, discovered the fourth satellite, which is the largest, with a telescope twelve feet long. Four of the others were discovered by Cassini; the fifth in 1671, which is next in brightness to the fourth; the third in December, 1672; and the first and second in the month of March, 1684. These four satellites were first observed by common refracting telescopes of 100 and 136 feet in length; but, after being acquainted with them, he could see them all, in a clear sky, with a tube of thirty-four feet. The sixth and seventh satellites, were discovered by Sir W. Herschel in August, 1789, soon after his large forty feet reflecting telescope was completed. These are nearer to Saturn than the other five; but, to avoid confusion, they are named in the order of their discovery. The following is the order of the satellites in respect of their distance from Saturn:

| Seventh. | Sixth. | First. | Second. | Third. | Fourth. | Fifth. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |



The motions and distances of these bodies have not been so accurately ascertained as those of Jupiter. The following statement contains a near approximation of their periods and distances. The seventh satellite, or that nearest to Saturn, is distant, 120,000 miles from the centre of the planet, about 80,000 from its surface, and only about 18,000 miles beyond the edge of the outer ring. It moves round the planet in twenty-two hours, thirty-seven minutes, a circuit of 377,000 miles, at the rate of 16,755 miles an hour. The sixth satellite, or the second from Saturn, is distant 150,000 miles, and finishes its revolution in one day, eight hours, fifty-three minutes. The first of the old satellites, or the third from Saturn, finishes its periodical revolution in one day, twenty-one hours, eighteen minutes, at the distance of 190,000 miles. The second (or fourth from Saturn,) in two days, seventeen hours, forty-four and three quarter minutes, at the distance of 243,000 miles. The third (fifth from Saturn,) in four days, twelve hours, fifty-five minutes, at the distance of 340,000 miles. The fourth (sixth from Saturn,) in fifteen days, twenty-two hours fifty-one minutes, at the distance of 788,000 miles. The fifth (seventh from Saturn,) in seventy-nine days, seven hours, and fifty-four and a half minutes, at the distance of 2,297,000 miles.

The orbits of the six inner satellites are inclined about thirty degrees to the plane of Saturn's orbit, and lie almost exactly in the plane of the rings, and therefore they appear to move in ellipses similar to the ellipses of the rings. But the orbit of the fifth or outer satellite, makes an angle with the plane of Saturn's orbit of 24 degrees, 45 minutes. These satellites, having their orbits inclined at so great angles to Saturn, cannot cross the body of that planet, or go behind it, or pass through its shadow, as Jupiter's satellites do, except on rare occasions, and hence they very seldom suffer eclipses or occultations. The only time when eclipses happen is near the periods when the ring is seen edgewise. The fifth or most distant satellite is sometimes invisible in the eastern part of its orbit, which is supposed to arise from one part of the satellite being less luminous than the rest. Sir W. Herschel observed this satellite through all the variations of its light, and concluded, as Cassini had done before, that it turned round its axis like our moon, in the same time that it performed its revolution round Saturn. In consequence of this rotation, the obscure part of its disk is turned towards the earth when in the part of its orbit east of Saturn; and the luminous portion of its surface is turned to the earth and becomes visible while it passes through the western part of its course.

Of these satellites the two innermost are the smallest and the most difficult to be perceived. They have never been discerned but with the most powerful telescopes, and then under peculiar circumstances. At the time of the disappearance of the ring, "they have been seen threading, like beads, the most infinitely thin fibre of light to which it is then reduced, and, for a short time, advancing off it at either end." Few astronomers besides Sir W. Herschel and his son have been able to detect these small bodies. The celebrated Schroeter and Dr. Harding, on the 17th, 20th, 21st, and 27th of February, 1798, obtained several views of the sixth satellite (the second from Saturn) by means of a reflecting telescope 13 feet long, carrying a power of 288. Their observations fully confirmed the accuracy of Sir W. Herschel's statement of the period of its revolution. The first and second satellites (third and fourth from Saturn) are the next smallest; the third (fifth from Saturn) is greater than the first and second; the fourth (sixth from Saturn) the most conspicuous and the most distant satellite, according to Sir John Herschel, is by far the largest, although it is not so conspicuous in one part of its orbit. In order to see any of the satellites of this planet, a good telescope, with a power of at least 70 or 80 times, is requisite, and with such a power only the two outermost satellites will be perceived. To perceive all the five old satellites requires a power of at least 200 times, and a considerable quantity of light.

*Magnitude of Saturn's Satellites.*—The precise bulk of these satellites has not yet been accurately determined. Sir John Herschel estimates the most distant satellite, which he thinks the largest, as not much inferior in size to the planet Mars, which is 4200 miles in diameter. The fourth satellite, which is the most conspicuous, cannot be supposed to be much inferior to it in bulk. But as the precise dimensions of most of the inner satellites cannot be estimated with accuracy, we shall not, perhaps, exceed the dimensions of these bodies if we suppose for the whole a general average of 3000 miles diameter for each. On this assumption, the surface of each satellite will contain 28,274,400 of square miles, which is nearly double the area of our moon. The area of all the seven satellites will therefore amount to 197,920,800 square miles, which is four times the quantity of surface on all the habitable parts of the earth. At the rate of 280 inhabitants to the square mile, these satellites would therefore contain 55,417,824,000, or more than *fifty-five thousand millions* of inhabitants, which is sixty-nine times the population of our globe.

These satellites will present a beautiful and variegated appearance in the firmament of Saturn; the nearest satellite, being only 80,000 miles from the *surface* of the planet, which is only the one third of the distance of the moon from the earth, will exhibit a very large and splendid appearance. Supposing it to be only about the diameter of our moon, it will present a surface nearly nine times larger than the moon does to us; and in the course of twenty-two and a half hours will exhibit all the phases of a crescent, half moon, full moon, &c., which the moon presents to us in the course of a month; so that almost every hour its phase will be sensibly changed, and its motion round the heavens will appear exceedingly rapid. While, in consequence of the diurnal rotation of Saturn, it will appear to move from east to west, it will also be seen moving with a rapid velocity among the stars in a contrary direction, and will pass over a whole hemisphere of the heavens in the course of eleven hours. The next satellite in order from Saturn, being only 110,000 miles from his surface, will also present a splendid appearance, much larger than our moon, and will exhibit all the phases of the moon in the course of sixteen hours. All the other satellites will exhibit somewhat similar phenomena, but in different periods of time. They will appear, when viewed from the surface of Saturn, of different sizes; some of them nine times larger than the moon appears to us, some three times, some double the size, and it is probable that even the most distant satellites will appear nearly as large as our moon, so that a most beautiful and sublime variety of celestial phenomena will be presented to a spectator in the heavens of Saturn, besides the diversified aspects of the rings to which we formerly adverted, all displaying the infinite grandeur and beneficence of the Creator.

### IV. ON THE SATELLITES OF URANUS.

This planet is attended by six satellites, all of which were discovered by Sir W. Herschel, to whom we owe the discovery of the planet itself. The second and fourth satellites were detected in January, 1787, about six years after the planet was discovered; the other four were discovered several years afterward, but their distances and periodical revolutions have not been so accurately ascertained as those of the two first discovered.

The *first* of these satellites, or the nearest to Uranus, completes its sidereal revolution in 5 days, 21 hours, and 25 minutes, at the distance of 224,000 miles from the centre of the planet. The *second* in 8 days, 17 hours, at the distance of 291,000 miles. The *third* in 10 days, 23 hours, at the distance of 340,000 miles. The *fourth* in 13 days, 11 hours, at the distance of 390,000 miles. The *fifth* in 38 days, one hour, 48 minutes, at the distance

of 777,000 miles. The *sixth* in 107 days, 16 hours, 40 minutes, at the distance of 1,556,000 miles.

These bodies present to our view some remarkable and unexpected peculiarities. Contrary to the analogy of the whole planetary system, *the planes of their orbits are nearly perpendicular to the ecliptic*, being inclined no less than 79 degrees to that plane. Their motions in these orbits are likewise found to be *retrograde*, so that, instead of advancing from west to east round Uranus, as all the other planets and satellites do, they move in the opposite direction. Their orbits are quite circular, or very nearly so, and they do not appear to have undergone any material change of inclination since the period of their discovery. "These anomalous peculiarities," says Sir John Herschel, "seem to occur at the extreme limits of the system, as if to prepare us for further departure from all its analogies in other systems which may yet be disclosed to us" in the remoter regions of space.

The satellites of Uranus are the most difficult objects to perceive of any within the boundary of the planetary system, excepting the two interior satellites of Saturn; and therefore few observers, excepting Sir William and Sir John Herschel, have obtained a view of them. Their magnitudes, of course, have never been precisely determined; but there is every reason to believe that they are, on an average, as large as the satellites of Saturn, if not larger, otherwise they could not be perceived at the immense distance at which they are placed from our globe. Supposing them, on an average, to be 3000 miles in diameter—and they can scarcely be conceived to be less—the surfaces of all the six satellites will contain 169,646,400 square miles, or about 3½ times the area of all the habitable portions of the earth; and which, at the rate formerly stated, would afford scope for a population of 47,500,992,000, or above forty-seven thousand millions, which is about sixty times the present number of the inhabitants of the earth.

The satellites of Uranus seldom suffer eclipses; but as the plane in which they move must pass twice in the year through the sun, there may be eclipses of them at those times; but they can be seen only when the planet is near its opposition. Some eclipses were visible in 1799 and 1818, when they appeared to ascend through the shadow of the planet in a direction almost perpendicular to the plane of its orbit. It is probable that this planet is attended with more satellites than those which have yet been discovered. It is not unlikely that two satellites at least revolve between the body of the planet and the first satellite; for the third satellite of Saturn is not nearly so far distant from the surface of that planet as the first satellite of Uranus is from its centre. But as the inner satellites may be supposed to be the smallest, and yet present as large a surface to the planet as the exterior ones, it is probable that, on account of their diminutive size, they may never be detected. It is likewise not improbable that two satellites may exist in the large spaces which intervene between the orbits of the fourth and fifth, and the fifth and sixth satellites. All these satellites will not only pour a flood of light on this distant planet, but will exhibit a splendid and variegated appearance in its nocturnal firmament.

The satellites of Jupiter, Saturn, and Uranus, of which we have given a brief description in the preceding pages, form, as it were, so many distinct planetary systems in connexion with the great system of the sun. The same laws of motion and gravitation which apply to the primary planets are also applicable to the secondary planets or moons. The squares of their periodical times are in proportion to the cubes of their distances. They are subject to the attraction of their primaries, as all the primary planets are attracted by the sun; and as the sun, in all probability, is carried round a distant centre along with all his attendants, so the satellites are carried round the sun along with their respective planets; partly by the influence of these planets, and partly by the attractive power of the great central luminary. Each of those secondary systems forms a system by itself, far more grand and extensive than the whole planetary system was conceived to be in former times. Even the system of Saturn itself, including its rings and satellites, contains a mass of matter more than a thousand times larger than the earth and moon. The system of Jupiter comprises a mass of matter nearly fifteen hundred times the size of these two bodies; and even that of Uranus is more than eighty times the dimensions of our terrestrial system.

## CHAPTER V.

### *On the Perfections of the Deity, as displayed in the Planetary System.*

All the works of nature speak of their Author in language which can scarcely be misunderstood. They proclaim the existence of an original, uncreated Cause, of an eternal

Power and Intelligence, and of a supreme agency which no created being can control. "The heavens" in a particular manner "declare the glory of God, and the firmament showeth forth his handiwork." When we consider the heavenly orbs in their size, their distance, the rapidity of their motions, and the regularity and harmony with which they perform their respective revolutions, it is obvious to the least attentive observer that such bodies could not have formed themselves, or have arranged their motions, their periods, and their laws in the beautiful order in which we now behold them. Motion of every kind supposes a moving power. As matter could not make itself, so neither can it set itself in motion. Its motion must commence from a power exterior to itself, and that power must correspond in energy to the *effect* produced. In the planetary system we find bodies a thousand times larger than the earth moving with a velocity sixty times greater than a cannon ball, and carrying along with them in their train other expansive globes in the same swift career. Such motions could only proceed from a power which is beyond calculation or human comprehension; and such a power can only reside in an uncreated, self-existent, and independent Intelligence. The *continuance* of such motions must likewise depend upon the incessant agency of the same Almighty Being, either directly, or through the medium of such subordinate agents as he is pleased to appoint for the accomplishment of his designs. In this respect the laws of motion, of attraction, gravitation, electricity, and other powers, are so many agents under the direction and control of the Almighty for carrying forward the plans of his physical and moral government of the universe.

The study of astronomy ought always to have in view as its ultimate object, to trace the Divine perfections as displayed in the phenomena of the heavens. For, as our poet Milton expresses it, "Heaven is as the book of God before us set, wherein to read his wondrous works." There is no scene we can contemplate in which the attributes of the Divinity are so magnificently displayed. It is in the heavens alone that we perceive a sensible evidence of the *infinity* of his perfections, of the grandeur of his operations, and of the immeasurable extent of his universal dominions. Even the planetary system, small as it is in comparison of the whole extent of creation, contains within it wonders of creating Omnipotence and skill which almost overpower the human faculties, and demonstrate the "eternal power and godhead" of Him who at first brought it into existence. To consider astronomy merely as a secular branch of knowledge, which improves navigation, and gives scope to the mathematician's skill, and to overlook the demonstrations it affords of the invisible Divinity, would be to sink this noble study far below its native dignity, and to throw into the shade the most illustrious manifestations of the glories of the Eternal Mind.

When we contemplate the stupendous globes of which the planetary system is composed, and the astonishing velocity with which they run their destined rounds, we cannot but be struck with an impressive idea of the POWER of the Deity; of the incomprehensible ENERGIES of the eternal mind that first launched them into existence. What are all the efforts of puny man as displayed in the machinery he has set in motion, and in the most magnificent structures he has reared, in comparison with worlds a thousand times larger than this earthly ball, and with *forces* which impel them in their courses at the rate of thirty thousand, and even a hundred thousand miles an hour! The mind is overpowered and bewildered when it contemplates such august and magnificent operations. Man, with all his imaginary pomp and greatness, appears, on comparison, as a mere microscopic animalcula, yea, as "less than nothing and vanity;" and such displays of the omnipotence of Jehovah are intended to bring down the "lofty looks of men," and to stain the pride of all human grandeur, "that no flesh should glory in his presence." Without materials, and without the aid of instruments or machinery, the foundations of the planetary system were laid, and all its arrangements completed. "He only *spake*, and it was done;" he only gave the *command*, and mighty worlds started into existence and run their spacious rounds. "By the word of the Lord were the heavens made, and all the host of them by the breath of his mouth." That Almighty Being who, by a single volition, could produce such stupendous effects, must be capable of effecting what far transcends our limited conceptions. His agency must be universal and uncontrollable, and no created being can ever hope to frustrate the purposes of his will or counteract the designs of his moral government. Whatever he has promised will be performed; whatever he has predicted by his inspired messengers must assuredly be accomplished. "For the kingdom is the Lord's, he is the Governor among the nations," and all events, and the movements of all intelligent beings, are subject to his sovereign control. "Though the mountains should be carried into the midst of the seas, and the earth reel to and fro like a drunkard;" yea, though this spacious globe should be wrapped in flames, and "all that it inherits be dissolved," yet that power which

brought into existence the planetary worlds, and has supported them in their rapid career for thousands of years, can cause "new heavens and a new earth, wherein dwelleth righteousness," to arise out of its ruins, and to remain in undiminished beauty and splendour.

"The heavens," says an inspired writer, "declare the glory of the Lord, and there is no speech nor language where their voice is not heard." Even the pagan nations were impressed with the power of a supreme intelligence from a contemplation of the nocturnal firmament. "When we behold the heavens," says Cicero, "when we contemplate the celestial bodies, can we fail of conviction? Must we not acknowledge that there is a Divinity, a perfect being, a ruling intelligence that governs, a God who is every where, and directs all by his power? Any one who doubts this may as well deny that there is a sun that enlightens us." Plato, when alluding to the motions of the sun and planets, exclaims, "How is it possible for such prodigious masses to be carried round for so long a period by any natural cause? for which reason I assert God to be the great and first cause, and that it is impossible it should be otherwise."

A very slight view of the planetary system is sufficient to impress our minds with an overpowering sense of the *grandeur* and *omnipotence* of the Deity. In one part of it we behold a globe fourteen hundred times larger than our world flying through the depths of space, and carrying along with it a retinue of revolving worlds in its swift career. In a more distant region of this system we behold another globe, of nearly the same size, surrounded by two magnificent rings, which would inclose 500 worlds as large as ours, winging its flight through the regions of immensity, and conveying along with it seven planetary bodies larger than our moon, and the stupendous arches with which it is encircled, over a circumference of five thousand seven hundred millions of miles. Were we to suppose ourselves placed on the nearest satellite of this planet, and were the satellite supposed to be at rest, we should behold a scene of grandeur altogether overwhelming; a globe filling a great portion of the visible heavens, encircled by its immense rings, and surrounded by its moons, each moving in its distinct sphere and around its axis, and all at the same time flying before us in perfect harmony with the velocity of 22,000 miles an hour. Such a scene would far transcend every thing we now behold from our terrestrial sphere, and all the conceptions we can possibly form of motion, of sublimity, and grandeur. Contemplating such an assemblage of magnificent objects moving through the ethereal regions with such astonishing velocity, we would feel the full force of the sentiments of inspiration: "THE LORD GOD OMNIPOTENT REIGNETH. His power is irresistible; his greatness is unsearchable; wonderful things doth he which we cannot comprehend." The *motions* of the bodies which compose this system convey an impressive idea of the agency and the energies of Omnipotence. One of these bodies, eighty times larger than the earth, and the slowest moving orb in the system, is found to move through its expansive orbit at the rate of fifteen thousand miles an hour; another at twenty-nine thousand miles in the same period, although it is more than a thousand times the size of our globe; another at the rate of eighty thousand miles; and a fourth with a velocity of more than a hundred thousand miles every hour, or thirty miles during every beat of our pulse. The mechanical forces requisite to produce such motions surpass the mathematician's skill to estimate or the power of numbers to express. Such astonishing velocities, in bodies of so stupendous a magnitude, though incomprehensible and overwhelming to our limited faculties, exhibit a most convincing demonstration of the existence of an agency and a power which no created beings can ever counteract, and which no limits can control. Above all, the central body of this system presents to our view an object which is altogether overpowering to human intellects, and of which, in our present state, we shall neve be able to form an adequate conception. A luminous globe, thirteen hundred thousand times larger than our world, and five hundred times more capacious than all the planets, satellites, and comets taken together, and this body revolving round its axis and through the regions of space, extending its influences to the remotest spaces of the system, and retaining by its attractive power all the planets in their orbits, is an object which the limited faculties of the human mind, however improved, can never grasp, in all its magnitude and relations, so as to form a full and comprehensive idea of its magnificence. But it displays in a most astonishing manner the GRANDEUR of Him who launched it into existence, and lighted it up "by the breath of his mouth;" and it exhibits to all intelligences a demonstration of his "eternal power and godhead." So that, although there were no bodies existing in the universe but those of the planetary system, they would afford an evidence of a *power* to which no limits can be assigned; a POWER which is infinite, universal, and uncontrollable.

The planetary system likewise exhibits a display of the *wisdom and intelligence* of the Deity. If it is an evidence of wisdom in an artist that he has arranged all the parts of a machine, and proportioned the movements of its different wheels and pinions so as exactly

to accomplish the end intended, then the arrangement of the planetary system affords a bright display of "the manifold wisdom of God." In the *centre* of this system is placed the great source of light and heat; and from no other point could those solar emanations be propagated, in an equable and uniform manner, to the worlds which roll around it. Had the sun been placed at a remote distance from the centre, or near one of the planetary orbits, the planets in one part of their course would have been scorched with the most intense heat, and in another part would have been subjected to all the rigors of excessive cold; their motions would have been deranged, and their present constitution destroyed. The enormous bulk of this central body was likewise requisite to diffuse light and attractive influence throughout every part of the system. The diurnal *rotations* of the planets evince the same wisdom and intelligence. Were these bodies destitute of diurnal motions, one half of their surface would be parched with perpetual day, and the other half involved in the gloom of a perpetual night. To the inhabitants of one hemisphere the sun would never appear, and to the inhabitants of the other the stars would be invisible; and those expansive regions of the universe, where the magnificence of God is so strikingly displayed, would be for ever veiled from their view. The *permanency* of the axes on which the planets revolve was likewise necessary, in order to the stability of the system and the comfort of its inhabitants; and so we find that their poles point invariably in the same direction or to the same points of the heavens, with only a slight variation scarcely perceptible till after the lapse of centuries. As the planets are of a spheroidal figure, had the direction of their axes been liable to frequent and sudden changes, the most alarming and disastrous catastrophes might have ensued. In such a globe as ours, the shifting of its axis might change the equatorial parts of the earth into the polar, or the polar into the equatorial, to the utter destruction of those plants and animals which are not capable of interchanging their situations. Such a change would likewise cause the seas to abandon their former positions, and to rush to the new equator; the consequence of which would be, that the greater part of the men and animals with which it is now peopled would be again overwhelmed in a general deluge, and the habitable earth reduced to a cheerless desart. But all such disasters are prevented by the permanent position of the axis of our globe and of the other planets during every part of their annual revolutions, as fixed and determined by Him who is "wonderful in counsel and excellent in working."

The same wisdom is conspicuous in so *nicely balancing and proportioning the magnitudes, motions, and distances of the planetary orbs.* We find that the larger planets move in orbits most remote from the smaller planets and from the centre of the system. If the great planets Jupiter and Saturn had moved in lower spheres and at no great distance from the smaller, their attractive force would have had a much more powerful influence than it now has in disturbing the planetary motions, and might have introduced considerable confusion into the system. But, while they revolve at so great distances from all the inferior planets, their influence is inconsiderable, and the slight perturbations they produce are not permanent, but *periodical;* they come to a limit, and then go back again to the same point as before. Again, *the law of gravitation,* by which the planets are directed in their motions, is also an evidence of Divine intelligence. The law is found to act reciprocally as the square of the distance; that is, at double the distance it has one fourth, and at triple the distance one ninth of the force; at one half the distance it has four times, and at one third the distance it has nine times the strength or influence. Now it could easily be shown, that a law directly opposite to this, or even differing materially from it, would not only derange the harmony of the system, but might be attended with the most disastrous consequences. If, for instance, a planet as large and as remote as Saturn had attracted the earth in proportion to the quantity of matter it contains, and, at the same time, *in any proportion to its distance;* in other words, had its attractive power been greater the further it was removed from us, it would have dragged our globe out of its course, deranged its motions, and, in all probability, deprived us of the security we now possess, and of all the prospects and enjoyments which depend upon its equable and harmonious movements. There is no contrivance in the system more wonderful than the *rings* of Saturn. That these rings should be separated thirty thousand miles from the body of the planet; that they should, notwithstanding, accompany the planet in its revolution round the sun, preserving invariably the same distance from it; that they should revolve round the planet every ten hours, at the immense velocity of more than a thousand miles in a minute; and that they should never fly off to the distant regions of space, nor fall down upon the planet, are circumstances which require adjustments far more intricate and exquisite than we can conceive, and demonstrate that the almighty contriver of that stupendous appendage to the globe of Saturn is "great in counsel and mighty in operation." Yet these adjustments,

in whatever they may consist, have been completely effected. For this planet has been flying through the regions of space in a regular curve for thousands of years, and the system of its satellites and rings still remains permanent and unimpaired as at its first creation.

An evidence of wisdom may likewise be perceived in the *distance* at which each planet is placed from the great central body of the system. In the case of our own globe, its distance from the sun is so adjusted as to correspond to the density of the earth and waters, to the temper and constitution of the bodies of men and other animals, and to the general state of all things here below. The quantity of light which the central luminary diffuses around us is exactly adapted to the structure of our eyes, to the width of their pupils, and the nervous sensibility of the retina. The heat it produces, by its action on the *caloric* connected with our globe, is of such a temperature as is exactly suited to the nature of the soil and to the constitution of the animal and vegetable tribes. It is placed at such a distance as to enlighten and warm us, and not so near as to dazzle us with its splendour or scorch us with its excessive heat; but to cheer all the tribes of living beings, and to nourish the soil with its kindly warmth. Were the earth removed fifty millions of miles further from the sun, every thing around us would be frozen up, and we should be perpetually shivering amid all the rigors of excessive cold. Were it placed as much nearer, the waters of the rivers and the ocean would be transformed into vapour; the earth would be hardened into an impenetrable crust; the process of vegetation would cease; and all the orders of animated beings would faint under the excessive splendour of the solar beams. There can be no doubt that the distances of the other planets are likewise adapted to the nature of the substances of which they are composed and the constitution of their inhabitants. We find that the *densities* of these bodies *decrease* in proportion to their distance from the sun; and it is highly probable that this is one reason, among others, why they are placed at different distances, and are thus adapted to the greater or less degree of influence which the central luminary may produce on their surfaces.

The *figures* of the planetary bodies likewise indicate contrivance and intelligence. They are all either of a spherical or spheroidal form, and this figure is evidently the best adapted to a habitable world. It is the most *capacious* of all forms, and contains the greatest quantity of area in the least possible space. It is the best adapted to motion, both annual and diurnal, every part of the surface being nearly at the same distance from the centre of gravity and motion. Without this figure there could have been no comfortable and regular alternations of day and night in our world as we now enjoy, and the light of the sun and the mass of waters could not have been equably distributed. Had the earth been of a cubical, prismatic, or pentagonal form, or of any other angular figure, some parts would have been comparatively near the centre of gravity, and others hundreds or thousands of miles further from it; certain countries would have been exposed to furious tempests, which would have overturned and destroyed every object, while others would have been stifled for want of currents and agitation in the air; one part would have been overwhelmed with water, and another entirely destitute of the liquid element; one part might have enjoyed the benign influence of the sun, while another might have been within the shadow of elevations a hundred miles high, and in regions of insufferable cold. In short, while one country might have resembled a paradise, others would have been transformed into a chaos, where nothing was to be seen but barrenness and hideous desolation; but the globular figure which the Creator has given to our world prevents all such inconveniences and evils, and secures to us all the advantages we enjoy from the equable distribution of light and gravity, of the waters of our seas and rivers, and of the winds and motions of the atmosphere; and arrangements similar or analogous are enjoyed by all the other planetary worlds, in consequence of the globular figure which has been impressed upon them.

The same Divine Wisdom is displayed throughout the solar system *in the nice adjustment of the projectile velocity to the attractive power*. The natural tendency of all motion, impressed by a single force, is to make the body move in a *straight line*. The projectile force originally given to the planets, if not counteracted, would carry them away from the sun, in right lines, through the regions of infinite space. On the other hand, had the planets been acted upon solely by an attractive power proceeding from the centre, they would have moved with an increased velocity towards that centre, and, in a short time, have fallen upon the body of the sun. Now the Divine Intelligence strikingly appears in nicely proportioning and balancing these two powers, so as to make the planets describe orbits nearly circular. If these powers had not been accurately adjusted, the whole system would have run into confusion. For, were the velocity of any planet double to what would make it move in a circle or ellipse, it would rush from its sphere through the regions of immensity, and never again return to its former orbit. Or, should half its velocity

be taken away, the planet would descend obliquely towards the sun till it became four times nearer him than before, and then ascend to its former place; and by ascending and descending alternately, would describe a very eccentric orbit, and would feel the influence of the solar light and power sixteen times greater in one part of its course than in another; which would prevent such a globe as ours, and probably all the planetary bodies, from being habitable worlds. But, in this respect, every part of celestial mechanism is adjusted with the nicest skill, and the whole system appears a scene of beauty, order, and stability worthy of the intelligence of Him "who hath established the world by his wisdom, and stretched out the heavens by his understanding." And as the power of gravitation was first impressed upon matter by the hand of the Creator, so its continued action is every moment dependent on his sovereign will. Were its influence to be suspended, the whole system would immediately dissolve and run into confusion. The centrifugal force of the planets, in whirling round their axes, would shatter them into pieces and dissipate their parts throughout the circumambient spaces; every portion of matter would fly in straight lines, according as the projectile force chanced to direct at the moment this power was suspended; and the regions of infinite space, instead of presenting a prospect of beauty and order, would become a scene of derangement, overspread with the wrecks of all the globes in the universe; so that the order and stability of universal nature entirely depends upon the will and the omnipotence of the Deity in sustaining in constant action the power of universal gravitation. Were it his pleasure that the material world should be dissolved and its inhabitants destroyed, he has only to interpose his Almighty fiat, and proclaim, "Let the power of attraction be suspended," and the vast universe would soon be unhinged and return to its original chaos.

In short, the depth of the Divine Wisdom might have been illustrated from the constant proportion between the times of the periodical revolutions of all the planets, primary and secondary, and the cubes of their mean distances; from the constancy and regularity of their motions, that, amid so immense a variety of moving masses, all should observe their due bounds and keep their appointed paths, to answer the great ends of their creation; from the exactness with which they run their destined rounds, finishing their circuits with so much accuracy as not to deviate from the periods of their revolutions a single minute in a hundred years; from the *distances* of the several planets from the sun, compared with their respective *densities*; from their velocities in their orbits compared with their distances from the central luminary; from the wonderful simplicity of the laws on which so much beauty, harmony, and enjoyment depend; and from various other considerations, all which would tend to demonstrate that He who framed the planetary system is "the only wise God," whose "understanding is infinite," and the depth of whose intelligence is "past finding out."

From what we have now stated, we may see what a beautiful and divine fabric the solar system exhibits. Like all the arrangements of Infinite Wisdom its foundations are plain and simple, but its superstructure is wonderful and diversified. The causes which produce the effects are few, but the phenomena are innumerable. While the ends to be accomplished are numerous and various, the means are the fewest that could possibly bring the design into effect. What a striking contrast is presented between the works of Omnipotence as they really exist, and the bungling schemes of the ancient astronomers? who, with all their cycles, epicycles, concentric and eccentric circles, their deferents, and solid crystalline spheres, could never account for the motions of the planetary orbs, nor explain their phenomena. The plans of the Almighty, both in the material world and in his moral government, are quite unlike the circumscribed and complex schemes of man. Like himself, they are magnificent and stupendous, and yet accomplished by means apparently weak and simple. All his works are demonstrations, not only of his existence, but of his inscrutable wisdom and superintending providence. As the accomplishments of every workman are known from the work which he executes, so the operations of the Deity evince his supreme agency and his boundless perfections. What being less than infinite could have arranged the solar system, and launched from his hand the huge masses of the planetary worlds? What mathematician could so nicely calculate their distances and arrange their motions? Or what mechanic so accurately contrive their figures, adjust their movements, or balance their projectile force with the power of gravitation? None but He whose power is supreme and irresistible, whose agency is universal, and whose wisdom is unsearchable.

In the last place, the planetary system exhibits a display of the GOODNESS of the Creator and of his superintending care. The goodness of God is that perfection of his nature by which he delights to communicate happiness to every order of his creatures. Now all the movements and arrangements of the planetary bodies are so ordered and directed as to act in subserviency to the happiness of sentient and intelligent beings. This is evidently the grand

design of all the wise contrivances to which we have adverted. The spherical figure given to all the planets for the regular distribution of the waters of the seas and rivers, and of the currents of the atmosphere; their rotation on their axes, to produce the alternate succession of day and night; the situation of the sun in the centre of the system, for the equable distribution of light and heat to surrounding planets; and an apparatus of rings and moons, to reflect a mild radiance in the absence of the sun, are contrivances which can only have a respect to the comfort and convenience of animated beings; for they can serve no purpose to mere inert matter devoid of life and intelligence, and the Creator, so far as we know, never employs *means* without a corresponding end in view. In our world, the utility of these arrangements, in order to our happiness, is obvious to the least reflecting mind. Without light our globe would be little else than a gloomy prison; for it is this that cheers the heart of man, and unveils to our view the beauties and sublimities of creation; and had the earth no rotation, and were the sun continually shining on the same hemisphere, the temperate zones as well as the equatorial regions would be parched with a perpetual day, the moisture of the soil evaporated, the earth hardened, vegetables deprived of nourishment, the functions of the atmosphere deranged, and numerous other inconveniences would ensue, from which we are now protected by the existing arrangements of nature; and as such contrivances are essential to the comfort of the inhabitants of the earth, so we have every reason to conclude that these and all the additional arrangements connected with other planets are intended to promote the enjoyment of the different orders of sensitive and intelligent existence with which they are peopled.

As the object of the wise contrivances of the Deity is the communication of happiness, it would be inconsistent with every rational view we can take of his wisdom and intelligence not to admit that *the same end* is kept in view *in every part of his dominions*, however far removed from the sphere of our immediate contemplation, and though we are not permitted in the mean time to inspect the minute details connected with the economy of other worlds; for the Creator must always be considered as consistent with himself, as acting on the same eternal and immutable principles at all times, and throughout every department of his empire. He cannot be supposed to devise means in order to accomplish important ends in relation to our world, while in other regions of creation he devises means *for no end at all*. To suppose, for a moment, such a thing possible, would be highly derogatory to the Divine character, and would confound all our ideas of the harmony and consistency of the attributes of him who is "the only wise God." We have, therefore, the highest reason to conclude, that not only this earth, but the whole of the planetary system, is a scene of *divine benevolence*; for it displays to our view a number of magnificent globes, with special contrivances and arrangements, all fitted to be the abodes of intelligent beings, and to contribute to their enjoyment. Every provision has been made to supply them with that *light* which unfolds the beauties of nature and the glories of the firmament. All the arrangements for its equable distribution have been effected, and several wonderful modes unknown in our world have been contrived for alleviating their darkness in the absence of the sun, all which contrivances are, doubtless, accompanied with many others which lie beyond the range of our conception, and which our remote distance prevents us from contemplating. In proportion, then, as the other planets exceed the earth in size, in a similar proportion, we may conceive, is the extent of that theatre on which the Divine goodness is displayed. If this "earth is full of the goodness of the Lord," if the benevolence of the Creator has distributed unnumbered comforts among every order of creatures here below, what must be the exuberance of his bounty, and the overflowing streams of felicity enjoyed in worlds which contain thousands of times the population of our globe! If a world which has been partly deranged by the sin of its inhabitants abounds with so many pleasures, what numerous sources of happiness must abound, and what ecstatic joys must be felt in those worlds where moral evil has never entered, where diseases and death are unknown, and where the inhabitants bask perpetually in the regions of immortality! Were we permitted to take a nearer view of the enjoyments of some of those worlds, were we to behold the magnificent scenery with which they are encircled, the riches of Divine munificence which appear on every hand, the inhabitants adorned with the beauties of moral perfection, and every society cemented by the bond of universal love, and displaying the virtues of angelic natures, it is highly probable that all the enjoyments of this terrestrial sphere would appear only "as the drop of a bucket and the small dust of the balance," and as unworthy of our regard in comparison of the overflowing fountains of bliss which enrich the regions and gladden the society of the celestial worlds. In this point of view what a glorious and *amiable* being does the eternal Jehovah appear! "God is love." This is his name and his memorial in all generations and throughout all worlds. Supremely happy in himself

and independent of all his creatures, his grand design in forming and arranging so many worlds could only be to display the riches of his beneficence, and to impart felicity, in all its diversified forms, to countless orders of intelligent beings and to every rank of perceptive existence. And how *extensive* his goodness is, not only throughout the planetary system, but over all the regions of universal nature, it is impossible for the tongues of men or angels to declare, or the highest powers of intelligence to conceive. But of this we are certain, that "Jehovah is good to all;" that "his bounty is great above the heavens;" and that "his tender mercies are over all his works."

## CHAPTER VI.

### *Summary View of the Magnitude of the Planetary System.*

Having, in the preceding pages, given a brief description of the principal facts and phenomena connected with the solar system, and offered a few reflections suggested by the subject, it may not be inexpedient to place before the reader a summary view of the magnitude of the bodies belonging to this system, as compared with the population and magnitude of the globe on which we live. In this summary statement I shall chiefly attend to the *area* or superficial contents of the different planets, which is the only accurate view we can take of their magnitudes, when we compare them with each other as habitable worlds. The population of the different globes is estimated, as in the preceding descriptions, at the rate of 280 inhabitants to a square mile, which is the rate of population in England, and yet this country is by no means overstocked with inhabitants, but could contain, perhaps, double its present population.

From the above statement, the real magnitude of all the moving bodies connected with the solar system may at once be perceived. If we wish to ascertain what proportion these magnitudes bear to the amplitude of our own globe, we have only to divide the different amounts stated at the bottom of the table by the area, solidity, or population of the earth. The amount of area, or the superficial contents of all the planets, primary and secondary, is 78,195,916,784; or above *seventy-eight thousand millions* of square miles. If this sum be divided by 197,000,000, the number of square miles on the surface of our globe, the quotient will be 397; showing that the surfaces of these globes are 397 times more expansive than the whole surface of the terraqueous globe; or, in other words, that they contain an amplitude of space for animated beings equal to nearly *four hundred worlds* such as ours. If we divide the same amount by 49,000,000, the number of square miles in the habitable parts of the earth, the quotient will be 1595; showing that the surface of all the planets contains a space equal to one thousand five hundred and ninety-five times the area of all the continents and islands of our globe. If the amount of population which the planets might contain, namely, 21,894,974,404,480, or nearly *twenty-two billions*, be divided by 800,000,000, the population of the earth, the quotient will be 27,368; which shows that the planetary globes could contain a population more than twenty-seven thousand times the population of our globe; in other words, if peopled in the proportion of England, they are equivalent to twenty-seven thousand worlds such as ours in its present

state of population. The amount of the third column expresses the number of solid miles comprised in all the planets, which is 654,-038,348,119,246, or more than *six hundred and fifty-four billions.* If this number be divided by 263,000,000,000, the number of cubical miles in the earth, the quotient will be 2483; which shows that the solid bulk of the other planets is two thousand four hundred and eighty-three times the bulk of our globe. Such is the immense magnitude of our planetary system, without taking into account either the sun or the hundreds of comets which have been observed to traverse the planetary regions.

Great, however, as these magnitudes are, they are far surpassed by that stupendous globe which occupies the centre of the system. The surface of the sun contains 2,432,800,-000,000 square miles (nearly two and a half billions.) If this sum be divided by 197 millions, the number of square miles on the earth's surface, the quotient will be 12,350, which shows that the surface of the sun contains *twelve thousand three hundred and fifty* times the quantity of surface on our globe. If the same sum be divided by 78,195,916,784, the number of square miles in all the planets, the quotient will be 31, showing that the area of the surface of the sun is *thirty-one* times greater than the area of all the primary planets, with their rings and satellites. The solid contents of the sun amount to 356,818,-739,200,000,000, or nearly three hundred and fifty-seven thousand billions of cubical miles, which number, if divided by 654,038,348,119,-246, the number of solid miles in all the planets, will produce a quotient of 545, which shows that the sun is five hundred and forty-five times larger than all the planetary bodies taken together. Such is the vast and incomprehensible magnitude of this stupendous luminary, whose effulgence sheds day over a retinue of revolving worlds, and whose attractive energy controls their motions and preserves them all in one harmonious system. If this immense globe be flying through the regions of space at the rate of sixty thousand miles an hour, as is supposed, and carrying along with it all the planets of the system, it presents to the mind one of the most sublime and overwhelming ideas of motion, magnitude, and grandeur which the scenes of the universe can convey.

Fig. 92.

Fig. 91.

The comparative magnitudes of the different bodies in the system are represented to the eye in Fig. 91, where the circle at the top, No. 1, represents Jupiter; No. 2, Saturn; No. 3, Uranus; No. 4, the Earth; adjacent to which, on the left, is the Moon; No. 5, Mars; No. 6, Venus; and No. 7, Mercury. The four small circles at the bottom are the planets Vesta, Juno, Ceres, and Pallas, whose proportional sizes cannot be accurately represented. The other small circles connected with Jupiter, Saturn, and Uranus, are intended to represent the satellites of these planets, which in general may be estimated as

considerably larger than our moon. These comparative magnitudes are only approximations to the truth; for it would require a large sheet were we to attempt delineating them with accuracy, but the figure will convey to the eye a *general* idea of the comparative bulks of these bodies, in so far as it can be conveyed by a comparison of their diameters;* but no representation on a plane surface can convey an idea of the *solid contents* of these globes as compared with each other. The reader will perceive the great disparity of globes, whose diameters do not differ very widely from each other, if he place a globe of twelve inches diameter beside one of eighteen inches diameter. Though these globes differ only six inches in their diameters, yet he will at once perceive that the eighteen-inch globe contains more than double the surface of the twelve-inch; and this *solid* space which it occupies contains 3⅜ times the space occupied by the smaller globe. Were the sun to be represented in its proportional size to Jupiter and the other planets, it would fill a space *twenty inches in diameter*. On the same scale in which the planets are delineated, Saturn's ring would occupy a space four and a half inches in diameter. From these representations we may see how small a space our earth occupies in the planetary system, and what an inconsiderable appearance it presents in comparison with Jupiter, Saturn, and Uranus. Fig. 92 represents the *proportional distances* of the primary planets from the sun, from which it will be seen that Saturn, which was formerly considered the most distant planet, occupies nearly the middle of the system.

In Fig. 93 is represented a comparative view of the earth and the rings of Saturn. The small circle at the right hand side represents the lineal proportion of our globe to those stupendous arches, so that the eye may easily perceive that hundreds of worlds such as ours could be inclosed within such expansive rings. Fig. 94 represents the proportion

Fig. 93.

which the sun bears to the planet Jupiter, the largest planetary orb in the system. The large circle represents the sun, and the small circle Jupiter. If the earth were to be represented on the same scale, it would appear like a point scarcely perceptible. It is chiefly by the aid of such tangible representations that the mind can form any idea approximating to the reality of such magnitudes and proportions; and, after all its efforts, its views of such stupendous objects are exceedingly imperfect and obscure.

## CHAPTER VII.

### *On the Method by which the Distances and Magnitudes of the Heavenly Bodies are Ascertained.*

There is a degree of skepticism among a certain class of readers in regard to the conclusions which astronomers have deduced respecting the distances and magnitudes of the celestial bodies. They are apt to suspect that the results they have deduced are *merely conjectural*, and that it is impossible for human beings to arrive at any thing like certainty, or even probability, in regard to distances so immensely great, and to magnitudes so far surpassing every thing we see around us on this globe. Hence it is that the assertions of astronomers as to these points are apt to be called in question, or to be received with a certain degree of doubt and hesitation, as if

* The reader will find a comparative view of the distances and magnitudes of the planets, engraved on a very large sheet, in "Burritt's Geography of the Heavens," published at Hartford, North America.

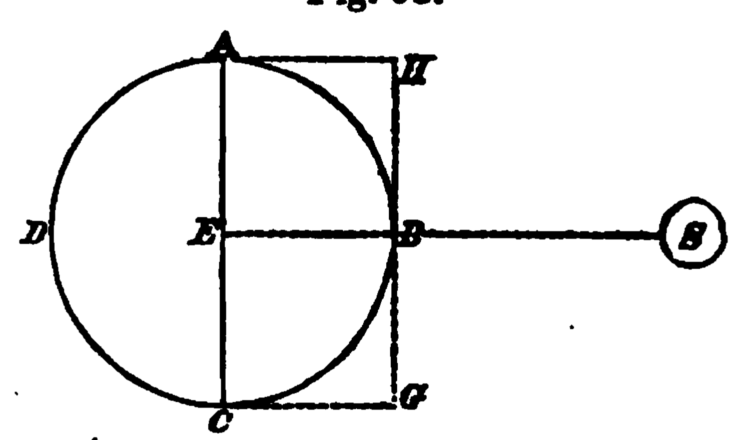
they were beyond the limits of truth or probability. And hence such persons are anxious to inquire, "How can astronomers find out such things?" "Tell us by what methods they can measure the distances of the planets and determine their bulks?" Such questions, however, are more easily proposed than answered; not from any difficulty in stating the principles on which astronomers proceed in their investigations, but from the impossibility, in many instances, of conveying an idea of these principles to those who are ignorant of the elements of geometry and trigonometry. A very slight acquaintance with these branches of the mathematics, however, is sufficient to enable a person to understand the mode by which the distances of the heavenly bodies are determined; but a certain degree of information on such subjects is indispensably requisite, without which no satisfactory explanation can be communicated.

In offering a few remarks on this subject, I shall, in the first place, state certain considerations, level to the comprehension of the general reader, which prove that the celestial bodies are much more distant from the earth, and, consequently, much larger than they are generally supposed to be by the vulgar, and those who are ignorant of astronomical science; and, in the next place, shall give a brief view of the mathematical principles on which astronomers proceed in their calculations.

When a common observer views the heavens for the first time, previous to having received any information on the subject, he is apt to imagine that the sun, moon, and stars are placed in the canopy of the sky at nearly the same distance from the earth, and that this distance is only a little beyond the region of the clouds; for it is impossible, merely by the eye, to judge of the relative distances of such objects. Previous to experience, it is probable that we could form no correct idea of the relative distances of any objects whatever. The young man who was born blind, and who was restored to sight at the age of thirteen, by an operation performed by Mr. Cheselden, could form no idea of the distances of the new objects presented to his visual organs. He supposed every thing he saw touched his eyes, in the same manner as every thing he felt touched his skin. An object of an inch diameter placed before his eyes, which concealed a house from his sight, appeared to him as large as the house. What he had judged to be round by the help of his hands he could not distinguish from what he had judged to be square; nor could he discern by his eyes whether what his hands had perceived to be above or below was really above or below; and it was not till after two months that he could distinguish pictures from solid bodies. In like manner we are apt to be deceived in our estimate of the distances of objects by the eye, particularly of those which appear in the concave of the heavens; and reason and reflection must supply the deficiency of our visual organs before we can arrive at any definite conclusions respecting objects so far beyond our reach.

That the heavenly bodies, particularly the sun, are much greater than they appear to the vulgar eye, may be proved by the following consideration: When the sun rises due east in the morning, his orb appears just as large as it does when he comes to the meridian at midday. Yet it can be shown that the sun, when he is on our meridian, is about 4000 miles nearer us than when he rose in the morning. This may be illustrated by the following figure.

Fig. 95.

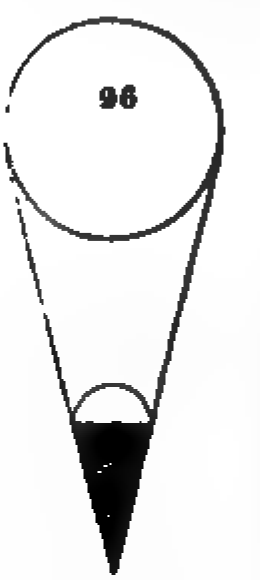


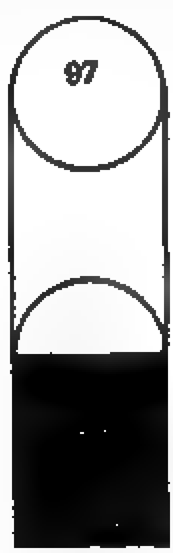

Let $A\ B\ C\ D$ represent the earth, and $S$ the sun at the point of his rising. Suppose the line $A\ E\ C$ to represent the meridian of a certain place, and $A$ or $E$ the place of a spectator. When the sun, in his apparent diurnal motion, comes opposite the meridian $A\ C$, he is a whole semidiameter of the earth nearer the spectator at $E$ than when he appeared in the eastern horizon. This semidiameter is represented by the lines $A\ H$, $E\ B$, $C\ G$, and is equal to 3965 miles. Now were the sun only four thousand miles distant from the earth, and, consequently, eight thousand miles from us at his rising, he would be nearly four thousand miles nearer us when on the meridian than at his rising; and, consequently, he would appear twice the diameter, and four times as large in surface as he does at the time of his rising. But observation proves that there is no perceptible difference in his apparent magnitude in these different positions; therefore the sun must be much more distant from the earth than four thousand miles. If his distance were only 120,000 miles, his apparent diameter would appear 1-30 part broader when on the meridian than at the time of his rising, and the difference could easily be determined; but no such difference is perceptible; therefore the sun is still more distant than one hundred and twenty thousand miles. And, as the *real* size of any

body is in proportion to its distance, compared with its *apparent* size, the sun must, from this consideration alone, be *more* than 1200 miles in diameter, and must contain *more* than nine hundred millions of cubical miles. But how much greater his distance and magnitude are than what is now stated cannot be determined from such observations.

The same idea may be illustrated as follows: Suppose a spectator at Edinburgh, which may be represented by the point *A* (Fig. 95,) and another at Capetown, in the southern extremity of Africa, about the time of our winter solstice, which position may be represented by the point *E*; both spectators might see the sun at the same moment, and he would appear exactly of the same size from both positions. Yet such spectators would be more than 4000 miles distant from each other in a *straight line*, and the observer at Capetown would be several thousands of miles nearer the sun than the one at Edinburgh. Now if the sun were only a few thousands of miles from the earth, he would appear of a very different magnitude to observers removed so far from each other, which is contrary to fact. Consequently, the sun must be at a very great distance from the earth, and his real size proportionable to that distance. For experience proves that objects which are of great magnitude may appear comparatively small when removed from us to a great distance. The lofty vessel, as it recedes from the coast towards the ocean, gradually diminishes in its apparent size, till at length it appears as a scarcely distinguishable speck on the verge of the horizon; and the aeronaut with his balloon, when they have ascended beyond the region of the clouds, appear only as a small dusky spot on the canopy of the sky, and sometimes entirely disappear.

The following argument, which is level to the comprehension of every reflecting mind, proves that the sun is larger than the whole globe of the earth, and that the moon is considerably less. Previous to the application of the argument to which I allude, it may be proper to illustrate the law of *shadows*. The law by which the shadows of globes are projected is as follows: When the luminous body is larger in diameter than the opaque body, the shadow which it projects converges to a point which is the vertex of a cone, as in Fig. 96. When the luminous and the opaque body are of an equal size, the shadow is cylindrical, and passes on from the opaque body to an indefinite extent, as represented in Fig. 97. When the luminous body is less than the opaque, the shadow extends in breadth beyond the opaque body, and grows broader and broader in proportion to its distance from the opaque globe, as in Fig. 98. This may be illustrated by holding a ball three or four inches in diameter opposite to a candle, when the shadow of the ball will be seen to be larger in diameter in proportion to the distance of the wall or screen on which the shadow is projected. Now it is well known, and will readily be admitted, that an eclipse of the moon is caused by the shadow of the earth falling upon the moon, when the sun, earth, and moon are nearly in a straight line with respect to each other; and that an eclipse of the sun is caused by the shadow of the moon falling upon a certain portion of the earth. Let *S* (Fig. 99) represent the sun; *E* the earth; and *M* the moon, nearly in a straight line, which is the position of these three bodies in an eclipse of the moon. The shadow of the earth, at the distance of the moon, is found to be of a less diameter than the diameter of the earth. This is ascertained by the time which the moon takes in passing through the shadow. The real breadth of that shadow, at the moon's distance from the earth, is about 5900 miles, sometimes more and sometimes less, according as the moon is nearer to or further from the earth; but the diameter of the earth is nearly 8000 miles; therefore the shadow of the earth gradually decreases in breadth in its progress through space, and, by calculation, it is found that it terminates in a point, as in Fig. 96, at the distance of about 850,000

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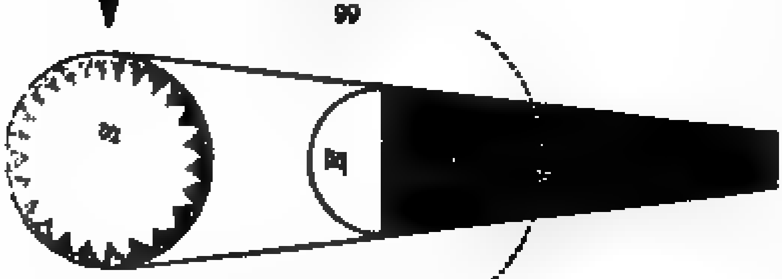

miles. But when a luminous globe causes the shadow of an opaque globe to converge towards a point, as in Fig. 96, the luminous body must be larger in diameter than the opaque one. The sun is the luminous body which causes the earth to project a shadow on the moon; this shadow, at the moon, is less in breadth than the diameter of the earth; therefore it inevitably follows *that the sun is larger than the earth*; but how much larger cannot be determined from such considerations.

From the same premises it necessarily follows that the moon is *less* than the earth. For the moon is sometimes completely covered by the shadow of the earth, although this shadow is less than the earth's diameter, and not only so, but sometimes takes an hour or two in passing through the shadow. If the sun were only equal to the earth in size, the earth's shadow would be projected to an indefinite extent, and be always of the same breadth, and might sometimes eclipse the planet Mars when in opposition to the sun. If the sun were less than the earth, the shadow of the earth would increase in bulk the further it extended through space (as represented in Fig. 98,) and would eclipse the great planets Jupiter, Saturn, and Uranus, with all their moons, when they happened to be near their opposition to the sun; and in this case they would be deprived of the light of the sun for many days together. In such a case, too, the sun would sometimes be eclipsed, to the earth by the planet Venus, when in its inferior conjunction with that luminary: an eclipse which might cause a total darkness of several hours continuance. In short, if the sun were less than any one of the planets, the system would be thrown into confusion by the shadows of all these bodies increasing in proportion to their distance, and interrupting, periodically, for a length of time, the communications of light and heat. But as none of these things ever happen, it is evident that the sun is much larger than the whole terraqueous globe.

All that requires to be taken for granted by the unlearned reader in this argument is, that the earth is a globular body; that an eclipse of the moon is caused by the shadow of the earth falling upon that orb; and that the shadow of the earth, at the distance of the moon, is of less breadth than the earth's diameter. The first two positions will readily be admitted; and the third position, respecting the breadth of the earth's shadow, may be received on the ground of what has been above stated, and on the authority of astronomers. For, if they were ignorant of this circumstance, they could not calculate eclipses with so much accuracy as they do, and predict the precise moment of the beginning and end of a lunar eclipse. If, then, any individual is convinced, from the consideration above stated, that the sun must be much larger than the earth, he has advanced one step in his conceptions of the magnificence of the heavenly bodies, and may rest with confidence on the assertions of astronomers in reference to the *real* distances and magnitudes of these orbs, although he may not be acquainted with the mathematical principles and investigations on which their calculations proceed.

Before proceeding to the illustration of the trigonometrical principles on which astronomers proceed in determining the true distances of the heavenly bodies, it may be requisite, for the unlearned reader, to give a description of the nature of angles and the mode by which they are measured. An angle is the opening between any two lines which touch each other in a point; and the width of the opening determines the extent of the angle, or the number of degrees or minutes it contains. Thus if we open a pair of compasses, the legs of which may be represented by *A B*, *B C*, Fig. 100, an angle is formed of different dimensions, according as the extremities of the legs are removed further from or brought nearer to each other. If the legs are made to stand perpendicular to each other, as in Fig. 101, the angle is said to be a *right angle*, and contains ninety degrees, or the fourth part of a circle. The walls of a room generally stand at right angles to the floor. If the legs be separated more than a right angle, they form what is termed an *obtuse angle*, as in Fig. 102. When the angle is less than a right angle, it is called an *acute angle*, as in Fig. 100, and, consequently, contains a less number of degrees than ninety. All angles are measured by the arc of a circle described on the angular point; and every circle, whether great or small, is divided into 360 equal parts, called degrees. Thus, if I want to know the quantity of an angle at *K*, (Fig. 103) I place one point of the compasses at the angular point *K*, and describe the arc of a circle between the two sides *L K*, *K M*, and whatever number of degrees of a circle is contained between them is the quantity or measure of the angle. If, as in the present case, the angle contains the eighth part of a circle or half a right angle, it is said to be an angle of forty-five degrees. A *triangle* is a figure which contains three angles and three sides, as *O P Q*, Fig. 104. It is demonstrated by mathematicians, that the three angles of every triangle, whatever proportion these angles may bear to each other, are exactly equal to two right angles, or 180 degrees. Thus, in the triangle *O P Q*, the angle at *Q* is a right angle, or ninety degrees, and the other two angles, *O* and *P*, are together equal to ninety de-

grees; so that, if one of these angles be known, the other is found by subtracting the number of degrees in the known angle from ninety.

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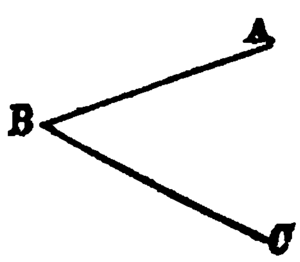


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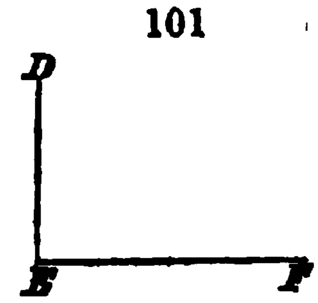


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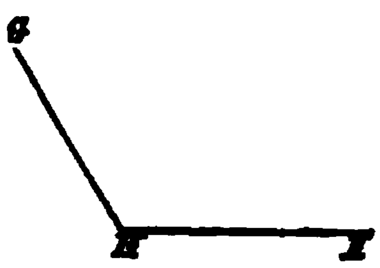


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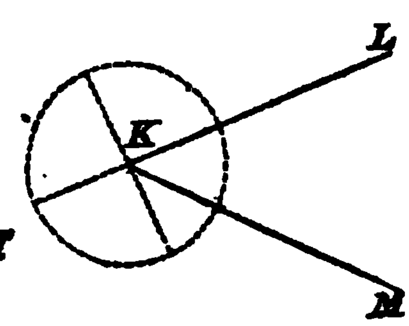


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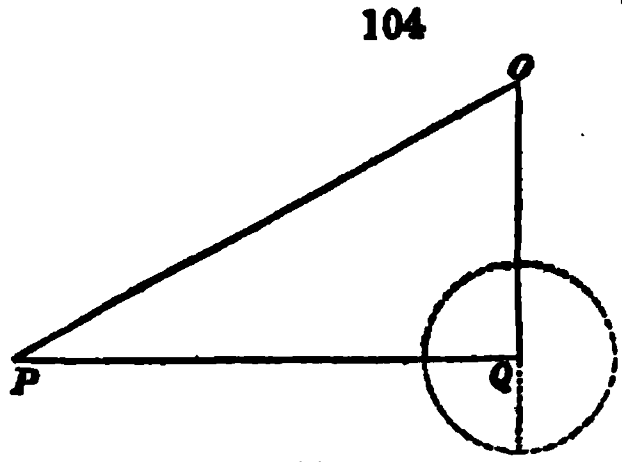


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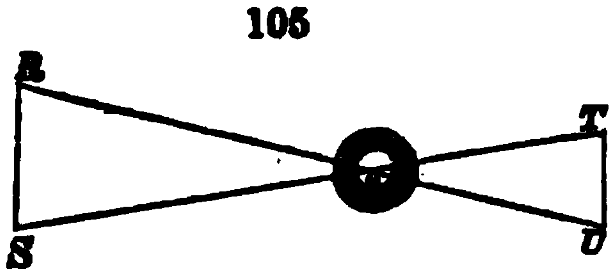


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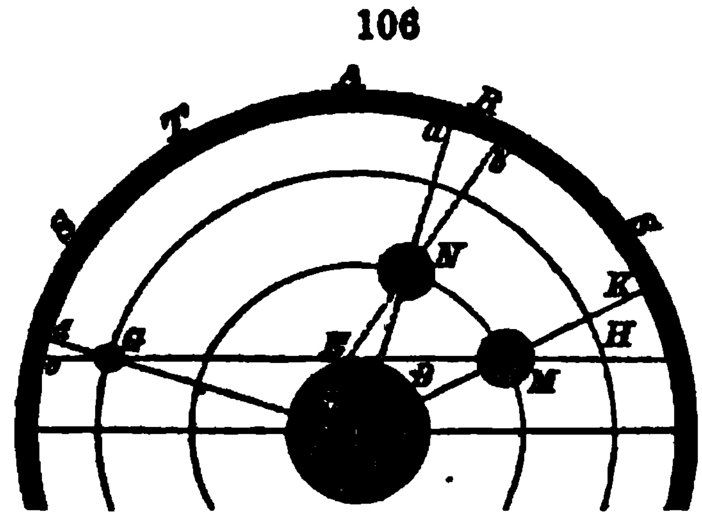


Thus, if the angle at $P$ be equal to thirty degrees, the angle at $O$ will be equal to sixty degrees. Hence, if any two angles of a triangle be known, the third may be found by substracting the sum of the two known angles from 180 degrees, the remainder will be the number of degrees in the third angle. All the triangles have their greatest sides opposite to their greatest angles; and if all the *angles* of the triangle be equal, the *sides* will also be equal to each other.

*If any three of the six parts of a triangle be known* (excepting the three angles,) *all the other parts may be known from them.* Thus, if the side $P\ Q$, and the angles at $P$ and $Q$ be known, we can find the length of the sides $P\ O$ and $O\ Q$. It is on this general principle that the distances and magnitudes of the heavenly bodies are determined.

In order to understand and apply this principle, it is necessary that we explain the nature of a *parallax*. A parallax denotes the change of the apparent place of any heavenly body, caused by being seen from different points of view. This may be illustrated by terrestrial objects as follows: Suppose a tree 40 or 50 yards distant from two spectators, who are 15 or 20 yards distant from each other; the one will perceive the tree in a line with certain objects near the horizon, which are considerably distant from those which appear in the direction of the tree, as viewed from the station occupied by the other spectator. The difference between the two points near the horizon where the tree appears to coincide to the two different spectators is the *parallax* of the object. If the tree were only 20 or 25 yards distant, the parallax would be twice as large; or, in other words, the points in the horizon where it was seen by the two spectators would be double the distance, as in the former case; and if the tree were two or three hundred yards distant, the parallax would be proportionally small. Or, suppose two persons sitting near each other at one side of a room, and a candle placed on a table in the middle of the room, the points on the opposite wall where the candle would appear to each of the two persons would be considerably distant from each other; and this distance may be called the parallax of the candle as viewed by the two observers. This may be illustrated by Fig. 105, where $R$ and $S$ may represent the positions of the observers; $a$ the candle or tree; and $T$ and $U$ the points on the opposite wall or in the horizon where the candle or the tree appears to the respective observers. The observer at $R$ sees the intermediate object at $U$; and the one at $S$ sees it in the direction $S\ T$. The angle $R\ a\ S$, which is equal to the angle $T\ a\ U$, is called the angle of parallax, which is the difference of position in which the object is seen by the two observers. If, then, the distance between the observers $R\ S$ be known, and the quantity of the angle $R\ a\ S$, the distance between the observers and the object can also be known by calculation.

Let us now apply this principle to the heavenly bodies. In Fig. 106 let the semicircle $S$, $T$, $A$, $R$, $S$, represent a section of the concave of the heavens; the middle circle, $E\ C$, the earth; $M$ the moon; $C$ the centre of the earth; and $E\ H$ the sensible horizon of a spectator at $E$. It is evident that if the moon be viewed from the earth at the point $E$, she

will be seen in the horizon at the point *H*; but were she viewed at the same time from *C*, the centre of the earth, she would appear among the stars at the point *K*, in a more elevated position than when seen from the surface of the earth at *E*. The difference between those two apparent positions of the moon, or the angle *K M H*, is called the moon's *horizontal parallax*. Astronomers know from calculation in what point of the heavens the moon would appear as viewed from the earth's centre; and they know from actual observation where she appears as viewed from the surface; and, therefore, can find the difference of the two positions, or the angle of parallax. This angle might likewise be found by supposing two spectators on different parts of the earth's surface viewing the moon at the same time. Suppose a spectator at *E*, who sees the moon in the horizon at *H*; and another observer, on the same meridian, at *B*, who sees her in his zenith at *K*; the parallax, as formerly, will be *K H*.

The parallax of a heavenly body decreases in proportion to its altitude above the horizon, and at the zenith (*A*) it is nothing, for the line from the centre of the earth coincides with that from the surface, as *C E A*. Thus, the parallax of the moon at *N* (*a b*) is less than the horizontal parallax, *K H*; but from the parallax observed at any altitude, the horizontal parallax can be deduced; and it is from this parallax that the distance of the moon or any other heavenly body is determined. ***The greater the distance of any body from the earth, the less is its parallax.*** Thus the heavenly body *G*, which is further from the earth than the moon, has a less parallax (*c d*) than that of the moon, *K H*.

Now the parallax of the moon being known, it is easy to find the distance of that orb from the earth; for in every triangle, if one side and two angles be known, the other angle and the other two sides can also be found. In the present case, we have a triangle *E M C*, in which the side *E C*, or the semidiameter of the earth, is known. The angle *M E C* is a right angle, or ninety degrees; and the parallactic angle *E M C* is supposed to be found by observation. From these *data*, by an easy trigonometrical calculation, the length of the side *C M*, or the distance of the moon from the centre of the earth, can be determined with the utmost precision, provided the angle of parallax has been accurately ascertained.

Before proceeding to illustrate by examples the method of calculating the distances of the heavenly bodies when the parallax is found, I shall present an example or two of the mode of computing the heights and distances of terrestrial objects, the principle on which we proceed being the same in both cases. Suppose it were required to find the height of the tower *C B* (Fig. 107,) we first measure the distance from the bottom of the tower, *B*, to a station at the point *A*, which suppose to be one hundred feet. From this station, by a quadrant or other angular instrument, we take the angle of elevation of the top of the tower, or the angle *C A B*, which suppose to be forty-seven and a half degrees.

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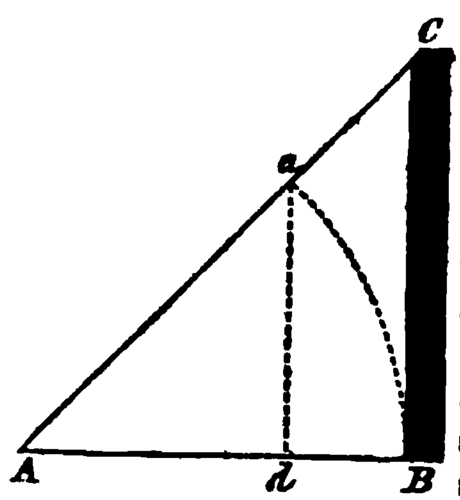


Here we have a triangle in which we have one side, *A B*, and two angles; namely, the angle at A$=47\frac{1}{2}°$, and the angle at *B*, which is a right angle, or 90°, as the tower is supposed to stand perpendicular to the ground; therefore the side *C B*, which is the height of the tower, can be found, and likewise the other side, *A C*, if required. To find *C B*, the height of the tower, we make *A B* the radius of the circle, a portion of which measures the angle *A*; and the side *B C*, or the height of the tower, becomes the tangent of that angle. And as there is a certain known proportion between the radius of every circle and the tangent, the height of the tower will be found by the following proportion: As the radius: is to the tangent of the angle *A*, $47\frac{1}{2}°$ : : so is the side *A B*, 100 feet: to *C B*, the height of the tower$=109\frac{1}{8}$ feet. The following is the calculation by logarithms:

| | |
|---|---|
| Logarithm of the 2d term—Tangent of $47\frac{1}{2}°$ . . . . | 10.0379475 |
| Logarithm of *A B*$=$100 feet—3d term . . . . . . . . | 2.0000000 |
| | 12.0379475 |
| Logarithm of radius—1st term | 10.0000000 |
| Logarithm of *C B*, 4th term$=$$109\frac{1}{8}$ feet$=$ . . . . . . | 2.0379475 |

By this calculation the height of the tower is found with the greatest nicety, provided the measurement of the side *A B*, and the angle *A*, have been taken with accuracy.

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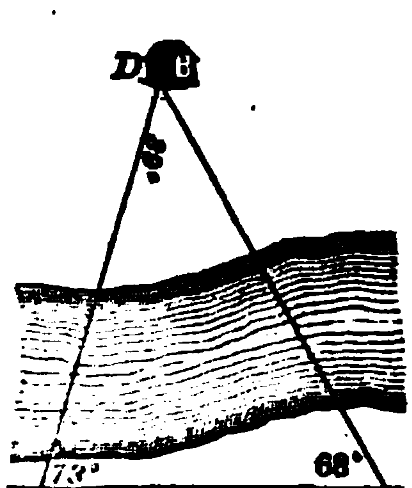


Again: Suppose it were required to measure the distance between a tree *E*, and a house *D*, on the opposite side of a river. We first measure a space from *E* to *F* (Fig. 108,) suppose 200 yards, in a right line, and then find the angles *E* and *F* each end of this line.

Suppose the angle at $E$ to be seventy-three degrees and the angle at $F$ sixty-eight degrees. As all the angles of a triangle are equal to two right anges, or 180°, if we add these two angles and subtract their sum from 180°, the remainder, 39°, will be the measure of the angle at $D$. It is a demonstrated proposition in trigonometry, that *in any plane triangle, the sides are in the same proportion as the sines of the opposite angles.* A *sine* is a line drawn through one extremity of an arc perpendicular upon the diameter or radius passing through the other extremity, as *a d* (Fig. 107.) In order, then, to find the distance ($E$ $D$) between the tree and the house on the other side of the river, we state the following proportion: As the sine of $D$, 38°, the angle opposite to $E$ $F$, the known side: is to the sine of the angle $F$, 68°, opposite the side sought, $E$ $D$: : so is the length of the line $E$ $F$=200 yards: to the distance, $E$ $D$, between the tree and the house=294⅘ yards. The following is the operation by logarithms:

| | |
|---|---|
| 2d term—Sine of angle, $F$=68° | 9.9671659 |
| 3d term—$E$ $F$=200 yards. Log. | 2.3010300 |
| | 12.2681959 |
| 1st term—Sine of angle, $D$=39° | 9.7988718 |
| 4th term—$D$ $E$=294⅘ yards= | 2.4693241 |

In these examples the logarithms of the second and third terms of the proportion are added, and from their sum the logarithm of the first term is subtracted, which leaves the logarithm of the fourth term; as in common numbers, the second and third terms are multiplied together, and their product divided by the first term; addition of logarithms corresponding to multiplication of whole numbers, and subtraction to division. The logarithms of common numbers, and of sines and tangents, are found in tables prepared for the purposes of calculation.

I shall now state an example or two in reference to the celestial bodies. Suppose it is required to find the distance of the moon from the earth. In Fig. 109, let $E$ $C$ represent the earth; $M$ the moon; $E$ the place of

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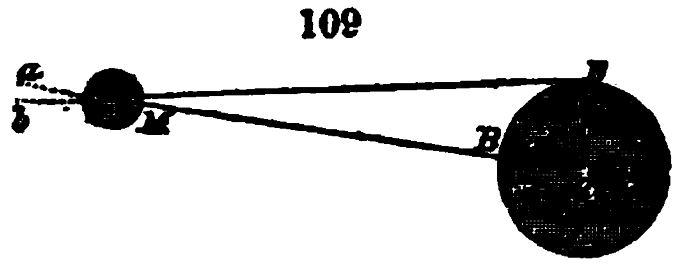

a spectator observing the moon in his sensible horizon; $E$ $M$ $b$ and $C$ $M$ $a$ the direction of the moon as seen from the centre of the earth at $C$, or from its surface at $B$; $a$ the place of the moon as seen from the centre, and $b$ its place as seen from the surface at $E$; or, in other words, the moon's *horizontal parallax.* This parallax, at the moon's mean distance from the earth, is found to be 57 minutes, 5 seconds. Here, then we have a triangle, $C$ $E$ $M$, of which we have one side and two angles given. The side given is the semidiameter of the earth, $E$ $C$, which is equal to 3965 miles; the angle at $E$ is a right angle, or ninety degrees, for it forms a tangent to the circle at $E$; the angle at $M$ is the horizontal parallax, which is found by observation. From these data, the side $M$ $C$, or the distance of the moon from the centre of the earth, may be easily found. If we make $C$ $M$ radius, $E$ $C$ will be the sine of the angle $M$; and the distance of the moon is found from the following proportion: As $E$ $C$, the sine of fifty-seven minutes, five seconds: is to 3965, the number of miles in the semidiameter of the earth: : so is $M$ $C$, the radius: to a fourth number, 238,800=$M$ $C$=the distance of the moon from the centre of the earth.

| | |
|---|---|
| 2d term—3965=the earth's semidiameter . . . . . . . | 3.598243 |
| 3d term—Radius . . . . . | 10.000000 |
| | 13.598243 |
| 1st term—Sine of 57 minutes, 5 seconds . . . . . . . . | 8.220215 |
| $M$ $C$, distance of the moon, 238,800 miles= . . . . . . | 5.378028 |

According to this calculation, the moon is two hundred and thirty-eight thousand, eight hundred miles from the earth. In round numbers we generally say that the moon is 240,000 miles distant; and, in point of fact, she is sometimes considerably more than 240,000 miles distant, and sometimes less than the number above stated, as she moves in an elliptical orbit, her horizontal parallax varying from 54 to above 60 minutes.

*To find the Diameter of the Moon.*—In Fig. 110 let $A$ $G$ $B$ represent the moon, and $C$ an observer at the earth. The apparent diameter of the moon at its mean distance, as measured by a micrometer, is 31 minutes, 26 seconds, represented by the angle $A$ $C$ $B$; the

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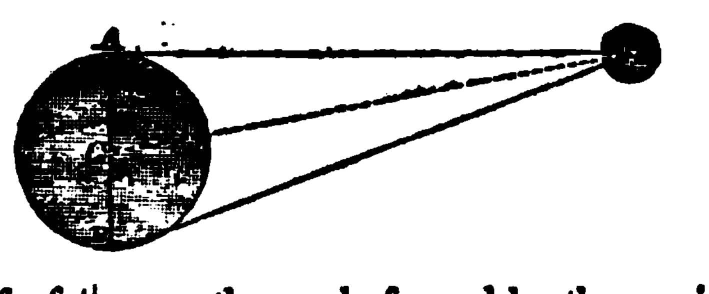

half of this, or the angle formed by the semidiameter of the moon, $A$ $C$ $G$, is 15 minutes, 43 seconds. The distance of the moon, $G$ $C$, is supposed to be found as above stated, namely, 238,800 miles. Here, then, we have

the angle $C\ A\ G$, which is a right angle, and the angle $A\ C\ G = 15'\ 43''$, which is found by observation; and the side $C\ G$, or the distance of the moon from the earth. We can therefore find the side $A\ G$, or the semidiameter of the moon, by the following proportion: As radius: is to $C\ G$, the distance of the moon, 238,800 miles:: so is the sine of $A\ C\ G$, $15'\ 43''$: to the number of miles contained in the moon's semidiameter, $A\ G = 1091\frac{1}{2}$, which, being doubled, gives 2183 miles as the diameter of the moon.

| | |
|---|---|
| 2d term—$C\ G = 238{,}800$—Log | 5.378028 |
| 3d term—Sine of $A\ C\ G$, $15'\ 43''$ | 7.660059 |
| | 13.038087 |
| 1st term—Radius . . . . | 10.000000 |
| Semidiameter of the moon, $1{,}091\frac{1}{2}$ = | 3.038087 |
| 2 | |
| Diameter of the moon = 2,183 | |

Such is the general mode by which the distances and magnitudes of the heavenly bodies are calculated. I am aware that the general reader, who is unacquainted with the principles of trigonometry, may find a little difficulty in comprehending the statements and calculations given above; but my design simply was to convey an idea of the *principle* on which astronomers proceed in their computations of the distances and bulks of the celestial orbs, and to excite those who are anxious to understand the subject, to engage in the study of plane trigonometry, a study which presents no great difficulty to any one who is already a proficient in common arithmetic. I conclude the subject with the following

*General Remarks.*—1. Before the bulks of the heavenly bodies can be determined, their *distances* from the earth must first be ascertained. When their distances are found, it is quite an easy matter to determine their *real* bulks from their *apparent* magnitudes. 2. *The semidiameter of the earth forms the groundwork of all our calculations respecting the distances of the celestial orbs.* Were we ignorant of the dimensions of the earth, we could not find the real distance and magnitude of any heavenly body; and it is owing to the comparatively small diameter of the earth that it becomes difficult in some cases to determine with accuracy the parallaxes of certain heavenly bodies. Were we placed on a planet such as Jupiter, whose diameter is more than eleven times that of our globe, it would be much more easy to find the parallaxes of the sun and planets. The parallaxes of Jupiter's moons, as observed from that planet, will form pretty large angles and be easily perceptible; and so likewise will be the parallaxes of the sun and the other planets which are visible from that globe. 3. *The chief difficulty in finding the distances of the heavenly bodies is to determine accurately the precise quantity of their parallaxes.* In the case of the moon there is no difficulty, as her horizontal parallax amounts to nearly one degree, and can be taken with the greatest nicety; but the sun's parallax is so small that it was some time before it was accurately determined. It was for this purpose, among others, that Captain Cook's first expedition to the Pacific Ocean was undertaken, in order that the astronomers connected with it might observe the transit of Venus at the island of Tahiti; since which time the sun's distance has been ascertained within the one eighty-seventh part of his true distance, which likewise determines very nearly the true proportional distance and magnitudes of all the planets. This circumstance accounts for the fact, that in books of astronomy published about a century ago, the distances and magnitudes of the sun and planets are estimated somewhat lower than they are now found to be, the improvements which have been made in the construction of astronomical instruments having enabled modern observers to measure parallactic angles with greater niceness and accuracy. 4. When the parallax of any heavenly body is once accurately found, and its apparent diameter measured, its real distance and bulk can be as certainly known as the price of any quantity of merchandise which is calculated by the rule of proportion. 5. From what has been stated above, we may learn the importance of knowing all the properties of a triangle, and the art of measuring angles. At first sight it may appear to be a matter of trivial importance to know that the radius of a circle bears a certain known proportion to the sine or tangent of a certain angle; that the *sides* of any triangle are in the same proportion as the *sines* of the opposite angles; and that the three angles of every plane triangle are exactly equal to two right angles. Yet such truths form the foundation of all the discoveries which have been made respecting the magnitudes and distances of the great bodies of the universe, and of the ample conceptions we are now enabled to form of the vast extent of creation, and of the attributes of its adorable Creator.

Those persons who feel themselves unable to comprehend clearly the principles and calculations above stated, may rest satisfied with the general deductions of astronomers respecting the distances and magnitudes of the sun and planets, from the following considerations: 1. *The general agreement of all modern astronomers as to these deductions.* However much astronomers may differ in regard to certain subordinate opinions or conjectures re-

specting certain phenomena, they all agree with respect to the bulks and distances of the planetary orbs, and the mode by which they are ascertained. If there were any fallacy in their calculations, such is the tendency of human nature to find fault, it would soon be pointed out. 2. The consideration of *the accuracy with which astronomers predict certain celestial phenomena* should induce persons unskilled in this science to rely on the conclusions deduced by astronomers. They are fully aware that the eclipses of the sun and moon are calculated and predicted with the utmost accuracy. The very moment of their beginning, middle, and end, and the places where they will be visible, are foretold to a nicety; the nature and magnitude of the eclipse, and all the circumstances connected with it, determined; and that, too, for more than a century to come. All the eclipses which have happened of late years were calculated more than half a century ago, and are to be found recorded in the writings of astronomers. They can likewise tell when Mars, Jupiter, or Saturn is to suffer an occultation by the moon, the time when it will begin and end, the particular part of the moon's limb behind which the planet will disappear, the point on the opposite limb where it will again emerge, and the places of the earth where the occultation will be visible. They can likewise predict the precise moment when any of the fixed stars—even those invisible to the naked eye—shall suffer an occultation by the moon or by any of the planets; and such occultations of the stars and planets are stated in the "Nautical Almanac," and similar publications, three or four years before they actually happen.

The precise time, likewise, when the planets Mercury and Venus will appear to pass across the sun's disk, has been predicted for a century before such events happened, and such transits have been calculated for several centuries to come, and will most assuredly take place, as they have hitherto done, if the laws of nature continue to operate as in ages past. Dr. Halley, in 1691, predicted the transit of Venus that happened in 1761, seventy years before it took place; and not only so, but he calculated the precise hour in which the planet would appear to touch the limb of the sun as seen from different places; the particular part of the sun's margin where the planet would appear and disappear, and the precise course it would take in passing across the disk of the sun; the appearance it would present in different regions of the globe, and the most proper places in both hemispheres were pointed out where either its beginning, middle, or end would be most distinctly observed, in order to accomplish the object in view; namely, the determination of the exact distance of the sun. All which calculations and predictions were ultimately found to be correct; and astronomers were sent to different parts of the globe to observe this interesting phenomenon, which happens only once or twice in the course of a century. The same astronomer calculated the period of a comet, distinguished by the name of "Halley's Comet," and predicted the periods when it would return. It was seen in England in 1682, and Dr. Halley calculated that it would again appear in this part of the system in 1758; and it accordingly made its appearance in December, 1758, and arrived at its perihelion on the 13th of March, 1759. The validity of these calculations and predictions has been again verified by the reappearance of the same comet in 1835, just at the time when it was expected, which proves that it completes its course in the period which had been predicted, namely, seventy-six years, and will, doubtless, again revisit this part of the system in the year 1911 or 1912. Astronomers can likewise point out, even in the daytime, the different stars and planets which are above the horizon, though invisible to the unassisted eye. I have sometimes surprised even gentlemen of intelligence by showing them, through an equatorial telescope, the star *Arcturus*, and, in a minute or two afterward, the star *Altair* in another part of the heavens, and the planet Venus in another quarter in the form of a brilliant crescent, while the sun was several hours above the horizon, and shining in its greatest brightness, and while these bodies are every moment shifting their apparent positions; all which is quite easy to be accomplished by every one who understands the motions of the heavenly bodies and the first principles of astronomy.

Now as the above facts are indisputable, and every one who feels an interest in the subject may satisfy himself as to their reality, it is evident to a demonstration that the principles of science on which such calculations and predictions proceed are not mere conjectures or precarious suppositions, but have a real foundation in the constitution of nature and in the fundamental laws which govern the universe. And as the knowledge of astronomers cannot be questioned in relation to the phenomena to which I refer, it would be unreasonable, and injurious to the moral characters of such men, to call in question their modes of ascertaining the distances of the sun and the planetary bodies, and the deductions they have made in relation to their astonishing magnitudes. There is no science whose principles are more certain and demonstrable than those of astronomy. No labour or expense has been spared to extend its observations, and to render them accurate in the extreme; and the noblest efforts of genius have been

called forth to establish its truths on a basis immutable as the laws of the universe; and, therefore, the man who questions the leading facts and deductions of this science only proclaims his own imbecility and ignorance.

## CHAPTER VIII.

### *On the Scenery of the Heavens, as viewed from the surfaces of the different Planets and their Satellites.*

This is a department of descriptive astronomy which is seldom noticed in books professedly written to illustrate the objects of this science. It is here introduced not only as an interesting subject of contemplation, but as an illustration of the *variety* which the Creator has introduced into the scenes of the universe, and as a collateral or presumptive argument in support of the doctrine of a plurality of worlds.

Before proceeding to the particular descriptions I intend to give, it may be proper to state the following *General Remarks*: 1. The different clusters of stars or the *constellations* will appear exactly the same when viewed from the other planets as to the inhabitants of our globe. For example, the constellations of *Orion* and of the *Great Bear* will appear of the same shape or figure, and all the stars of which they are composed will appear to have the same arrangement and the same relative distances from each other and from neighbouring stars, as they do to us. 2. The *apparent magnitudes* of the fixed stars will appear exactly the same as they do when viewed from our world; that is, they will appear no larger than shining points of different magnitudes, even when viewed from the most distant planets. The reason of this and of the preceding position is obvious from the consideration of the *immense distance* of those bodies; for although we are 190 millions of miles nearer some of the fixed stars at one time of the year than at another, yet there appears no sensible difference in their size or arrangement, and although we were placed on the remotest planet of the system, we have no reason to believe that any material difference in this respect would be perceived; for the distances of the remoter planets bear no sensible proportion to the distances of the fixed stars. Even the distance of the planet Uranus, great as it is, which would require four hundred years for a cannon ball to move over the space which intervenes between that orb and us, is less than the ten thousandth part of the distance of the nearest star; and, therefore, can produce no sensible difference in the general aspect of the starry firmament. 3. Though the general arrangement of the stars and constellations will appear the same as to us, yet the different directions of the axes of some of the planets from that of the earth *will cause a different appearance in their apparent diurnal revolutions*. Some stars which appear in our equator may, in other planets, appear near one of their poles, and our pole star may appear near their equator.

In the following descriptions it is taken for granted that the general laws of vision are materially the same in all the planetary bodies as in that part of the system which we occupy. Of this we have no reason to doubt, as the same identical light which illuminates the earth likewise enlightens all the planets and their satellites. It originates from the same source, it is refracted and reflected by the same laws, and must produce colours similar or analogous to those which diversify the surface of our globe; though, perhaps, susceptible of numerous modifications in other regions, according to the nature of the atmospheres through which it passes, and the quality of the objects on which it falls. The descriptions that follow likewise proceed on the supposition that the *extent of vision* is the same as ours. This, in all probability, is not the case. It is more probable that, in certain worlds, the organs of vision of their inhabitants may be far more exquisite than ours, and capable of surveying with distinctness a much more extensive range of view. But as we are ignorant of such particulars, we can only proceed on the assumption of what would appear to eyes constituted like ours were we placed on the surfaces of the different planets.

*Scenery of the Heavens from the Planet Mercury.*—This planet being so near the sun has prevented us from discovering various particulars which have been ascertained in relation to several of the other planets; and therefore, little can be said respecting its celestial scenery. The starry heavens will appear to move around it every twenty-four hours, as they do to us, if the observations of M. Schroeter, formerly stated (p. 33) be correct; but the direction of its axis of rotation is not known, and, therefore, we cannot tell what stars will appear near its equator or its poles. The sun will present a surface in the heavens seven times as large as he does to us, and, of course, will exhibit a very august and brilliant appear-

ance in the sky, and will produce a corresponding brightness and vividness of colour on the objects which are distributed over the surface of the planet. Both Venus and the earth will appear as *superior* planets; and when Venus is near its opposition to the sun, at which time it will rise when the sun sets, it will present a very brilliant appearance to the inhabitants of Mercury, and serve the purposes of a small moon, to illuminate the evenings in the absence of the sun. As Venus presents a full enlightened hemisphere at this period to the inhabitants of Mercury, it will exhibit a surface six or seven times larger than it does to us when it shines with its greatest brilliancy, and, therefore, will appear a very bright and conspicuous object in the firmament of this planet. At all other times it will appear at least two or three times larger than it ever does as seen from the earth. It will generally appear round; but at certain times it will exhibit a gibbous phase, as the planet Mars frequently does to us. It will never appear to the inhabitants of Mercury in the form of a crescent or a half moon, as it sometimes does through our telescopes. There is no celestial body within the range of this planet with which we are acquainted which will exhibit either a half moon or a crescent phase, unless it be accompanied with a satellite. The earth is another object in the firmament of Mercury which will appear next in splendour to Venus. The earth and Venus are nearly of an equal size, Venus being only 130 miles less in diameter than the earth; but the earth being nearly double the distance of Venus from Mercury, its apparent size, at the time of its opposition to the sun, will be only about half that of Venus. The earth, however, at this period, will appear in the sky of Mercury of a size and splendour three or four times greater than Venus does to us at the period of its greatest brilliancy. Our moon will also be seen like a star accompanying the earth, sometimes approaching to or receding further from the earth, and sometimes hidden from the view by passing across the disk of the earth or through its shadow. It will probably appear about the size and brightness of Mars or Saturn, as seen in our sky. The earth with its satellite, and Venus, will be seen near the same point of the heavens at the end of every nineteen months, when they will for some time appear the most conspicuous objects in the heavens, and will diffuse a considerable portion of light in the absence of the sun. At other periods, the one will rise in the eastern horizon as the other sets in the western, so that the inhabitants of Mercury will seldom be without a conspicuous object in their heavens, diffusing a lustre far superior to that of any other stars or planets. The earth will be in opposition to the sun every four mouths, and Venus after a period of five months. The planets Mars, Jupiter, and Saturn will appear nearly as they do to us, but with a somewhat inferior degree of magnitude and brilliancy, particularly in the case of Mars. The period of the annual revolution of Mercury being eighty-eight days, the sun will appear to move from west to east through the circle of the heavens at a rate more than four times greater than his apparent motion through the signs of our zodiac.

*Appearance of the Heavens as viewed from Venus.*—To the inhabitants of this planet the heavens will present an aspect nearly similar to that of Mercury, with a few variations. Mercury will be to Venus an *inferior* planet, which will never appear beyond thirty-eight or forty degrees of the sun. It will appear in the evening after sunset for the space of two or three hours when near its elongation, and in the morning before sunrise when in the opposite part of its course, and will alternately be a morning and an evening star to Venus, as that planet is to us, but with a less degree of splendour. The most splendid object in the nocturnal sky of Venus will be the *earth*, when in opposition to the sun, when it will appear with a magnitude and splendour five or six times greater than either Jupiter or Venus appears to us at the time of their greatest brilliancy. It will serve, in a great measure, the purpose of a moon to Venus, if this planet have no satellite, and will cause the several objects on its surface to project distinct and well-defined shadows, as our moon does when she appears a crescent. Our moon, in its revolutions round the earth, will likewise appear a prominent object in the heavens, and will probably appear about the size that Jupiter appears to us. Her occultations, eclipses, and transits across the earth's disk will be distinctly visible. With telescopes such as the best of ours the earth would appear from Venus a much larger and more variegated object than any of the planets do to us when viewed with high magnifying powers. The forms of our different continents, seas, and islands, the different strata of clouds in our atmosphere, with their several changes and motions, and the earth's diurnal rotation, would, in all probability, be distinctly perceived. Even the varieties which distinguish the surface of our moon would be visible with telescopes of high magnifying power. The circumstances now stated prove the connexion of the different parts of the planetary system with one another, and that the Creator has so arranged this system as to render one world, in a certain degree, subservient to the benefit of another. The earth serves as a large and splended moon to the lunar inha-

bitants; it serves, in a certain degree, the purpose of a small moon to Mercury; it serves the purpose of a larger moon, by exhibiting a surface and a radiance four times greater to the inhabitants of Venus; and it serves as a morning and an evening star to the planet Mars. So that, while we feel enjoyment in contemplating the moon walking in brightness, and hail with pleasure the morning star as the harbinger of day, and feel a delight in surveying those nocturnal orbs through our telescopes, the globe on which we dwell affords similar enjoyments to the intellectual beings in neighbouring worlds, who behold our habitation from afar as a bright speck upon their firmament, diffusing amid the shades of night a mild degree of radiance. From Venus the planets Saturn and Jupiter will appear nearly as they do to us, but the planet Mars will appear considerably smaller. The sun in this planet will present a surface twice as large as he does in our sky, and will appear to make a revolution round the heavens in the course of seven months and a half, which completes the year of Venus.

*The Heavens as viewed from Mars.*—From this planet the earth will at certain periods be distinctly seen, but it will present a different aspect both in its general appearance and its apparent motions from what it does to the inhabitants of Venus. To Mars the earth is an inferior planet, whose orbit is *within* the orbit of Mars. It will therefore, be seen only as a morning and an evening star, as Venus appears to us; but with a less degree of magnitude and brightness, since Mars is at a greater distance from the earth than the earth is from Venus. It will present to Mars successively the form of a *crescent*, a *half moon*, and a *gibbous* phase, but will seldom or never be seen as a full enlightened hemisphere, on account of its proximity to the sun, when its enlightened surface is fully turned towards the planet; nor will it ever appear further removed from the sun, either in the mornings or evenings, than forty-eight degrees, so that the earth will never appear in the firmament of Mars about midnight. The earth will likewise be sometimes seen to pass across the sun's disk like a round black spot, as Venus and Mercury at certain periods appear to us; but the planet Mercury will never be seen from Mars on account of its smallness and its nearness to the sun; for at its greatest elongation it will be only a few degrees from the sun's margin, and will consequently be immersed in his rays. The only time in which it might happen to be detected will be when it makes a transit across the solar disk. Venus will be as seldom seen by the inhabitants of Mars as Mercury is to us. Our moon will likewise be seen from Mars like a small star accompanying the earth, sometimes appearing to the east and sometimes to the west of the earth, but never at a greater distance from each other than fifteen minutes of a degree, or about half the apparent breadth of the moon; and with telescopes such as ours all its phases and eclipses might be distinctly perceived. The planets Jupiter and Saturn will appear to Mars nearly as they do to us. At the time of Jupiter's opposition to the sun that planet will appear a *slight degree* larger, as Mars is then fifty millions of miles nearer it than we are; but Saturn will not appear sensibly larger than to us; and it is likely that the planets Uranus, Vesta, Juno, Ceres, and Pallas will not be more distinguishable than they are from our globe. The point *Aries*, on the ecliptic of Mars, or one of the points where its ecliptic and equator intersect each other, corresponds to 19° 28′ of our sign *Sagittarius*. In consequence of this, the poles of Mars will be directed to points of the heavens considerably different from our polar points, and its equator will pass through a different series of stars from that which marks our equator, which will cause the different stars and constellations in their apparent diurnal revolution to present a different aspect from what they do in their apparent movements round our globe.

*The Heavens, as viewed from Vesta, Juno, Ceres, and Pallas.*—These planets, being so very nearly at the same mean distance from the sun, the appearance of the heavens will be nearly the same to the inhabitants (if any) of each of these bodies. The planet Jupiter will be the most conspicuous object in the nocturnal sky of all these planets, and will appear with nearly three times the size and splendour that he does when seen from the earth, so as to exhibit the appearance of a small brilliant moon. Saturn will appear somewhat larger and brighter than to us, but the difference in his appearance will be inconsiderable; nor will Uranus be more distinctly visible than from the earth. At other times, when near their conjunction with the sun, these planets will appear smaller than to us. Mars will sometimes appear as a morning and an evening star, but he will always be in the immediate neighbourhood of the sun, and will present a surface much less in apparent size than he does to the earth. The earth will seldom be seen on account of its proximity to the sun; and Venus and Mercury will be altogether invisible, unless when they transit the solar disk. It is likely that, at certain times, the planets Vesta, Juno, Ceres, and Pallas will exhibit an uncommon, and occasionally a brilliant appearance in the firmament of each other. As their distances from

the sun are so nearly the same, they may occasionally approach each other so as to be ten times nearer to one another in one part of their course than at another. It is even possible that they might approach within a few miles of each other, or even come into collision. These different positions in which they may be placed in relation to one another will doubtless produce a great variety in the appearances they present in their respective firmaments; so that at one time they may present in the visible firmament a surface a hundred or even two hundred times greater than they do in other parts of their annual revolutions. It is probable, therefore, that the diversified aspects of these planets, in respect to each other, will form the most striking phenomena which diversify their nocturnal heavens. In consequence of the great eccentricity of the orbit of Pallas, the sun will appear much larger to this planet in one part of its revolution than it does at another.

*Celestial Scenery from Jupiter.*—The only planet whose appearance will be conspicuous in the firmament of Jupiter is the planet *Saturn*, which will appear with a surface four times greater than is exhibited in our sky, and will appear larger than either Jupiter or Venus does to us, particularly at the time of its opposition to the sun. At certain other periods, when near the time of its conjunction with the sun, it will appear considerably smaller than when viewed from the earth; as, at such periods, Saturn is nearly fourteen hundred millions of miles distant from Jupiter, while it is never beyond ten hundred millions from the earth, even at its remotest distance. The planet Uranus, which is scarcely visible to our unassisted sight, will not be much more distinguishable at Jupiter than with us, even at the period of its opposition, although Jupiter is at that time 400,000,000 of miles nearer it than a spectator on the earth. At other times, when near its conjunction with the sun, it will be 2,300,000,000 of miles from Jupiter, which is 400,000,000 of miles more distant than it ever is from us. Mars will scarcely be seen from Jupiter, both on account of his smallness and his proximity to the sun; for at his greatest elevation he can never be more than eighteen degrees from that luminary. The earth, too, will be invisible from Jupiter, both on account of its small size, its distance, and its being in the immediate vicinity of the sun, and immersed in its rays; so that the inhabitants of this planet will scarcely suspect that such a globe as that on which we dwell exists in the universe. It is a humiliating consideration to reflect, that before we have passed over one fourth part of the extent of our system, this earth, with all its kingdoms and fancied grandeur, of which mortals are so proud, vanishes from the sight, as if it were a mere atom in creation, and is altogether unnoticed and unknown. It is calculated to convey a lesson of *humility* and of humanity to those proud and ambitious mortals who glory in their riches, and in the small patches of earthly territory they have acquired at the expense of the blood of thousands of their fellow-men, and who fancy themselves to be a species of demigods, because they have assisted in the conquest of nations, and in spreading ruin and devastation over the earth. Let us wing our flight to Jupiter or Saturn, which appear so conspicuous in our nocturnal sky, and before we have arrived at the middle point of the planetary system this globe on which we tread, with all the proud mortals that dwell upon its surface, vanishes from the sight as a particle of water, with its microscopic animalculæ, dropped into the ocean, disappears for ever. In those regions more expansive and magnificent scenes open to view, and their inhabitants, if ever they have heard of such beings as fallen man, look down with an eye of pity and commiseration, and view their characters and conduct with a holy indignation and contempt.

Venus and Mercury will, of course, be altogether invisible from the surface of Jupiter, and it is questionable whether even the planets Vesta, Juno, Ceres, and Pallas will be perceived. But although so few of the primary planets are seen in the nocturnal sky of this planet, its firmament will present a most splendid and variegated aspect by the diversified phases, eclipses, and movements of the satellites with which it is encircled; so that its inhabitants will be more charmed and interested by the phenomena presented by their own moons than by their contemplation of the other bodies of the system. But as I have already described the appearances of the moons, as seen from Jupiter (p. 122, chap. iv. sec. ii.) it is unnecessary to enlarge.

*Scenery of the Heavens as viewed from Saturn.*—The firmament of Saturn will unquestionably present to view a more magnificent and diversified scene of celestial phenomena than that of any other planet of our system. It is placed nearly in the middle of that space which intervenes between the sun and the orbit of the remotest planet. Including its rings and satellites, it may be considered as the largest body or system of bodies within the limits of the solar system; and it excels them all in the sublime and diversified apparatus with which it is accompanied. In these respects Saturn may justly be considered as the sovereign among the planetary hosts. The prominent parts of its celestial scenery may be considered as belonging to its own system of rings and satellites, and the views which will

occasionally be opened of the firmament of the fixed stars; for few of the other planets will make their appearance in its sky. Jupiter will appear alternately as a morning and an evening star, with about the same degree of brilliancy it exhibits to us; but it will seldom be conspicuous except near the period of its greatest elongation, and it will never appear to remove from the sun further than thirty-seven degrees, and, consequently, will not appear so conspicuous, nor for such a length of time, as Venus does to us. Uranus is the only other planet which will be seen from Saturn, and it will there be distinctly perceptible, like a star of the third magnitude, when near the time of its opposition to the sun. But near the time of its conjunction it will be completely invisible, being then eighteen hundred millions of miles more distant than at the opposition, and eight hundred millions of miles more distant from Saturn than it ever is from the earth at any period. All the other eight planets, together with our moon, will be far beyond the reach of a spectator in Saturn, unless he be furnished with organs of vision far superior to ours in their "space-penetrating power." It is not improbable that more *comets* will be seen in their course from the sun, from the distant regions in which Saturn moves, than from that part of the system in which we are placed. Some of these bodies, when they pass beyond the limits of our view, will be visible beyond the orbit of Saturn; and as their motions in those distant spaces are much slower than when near the sun, they will remain visible for a longer time, when they happen to make their appearance, than they do when passing through our part of the system.

Having already given a pretty full description of the appearance of the rings of this planet as viewed from its surface (p. 87–91) and of the phenomena exhibited by its satellites (p. 126,) it is unnecessary to introduce the subject in this place. I shall only remark further, in regard to the rings which encompass this planet, that, besides the light they reflect on the planet, and the brilliant aspect they present in its firmament, they cast a great diversity of shadows upon the surface of the planet, of different breadths at different times and places, and it will require a considerable degree of attention and investigation on the part of its inhabitants to determine whence the shadows proceed. For when the dark sides of the rings are turned towards them, they will, in all probability, be invisible in their sky, as the dark side of the moon or of Venus is to us; and, therefore, they may be at a loss, in some instances, to discover the causes of such varieties of light and shade. For, although *we* are placed in a convenient position to perceive that they are in reality *complete rings* which environ the body of Saturn, yet it will not be so easy for *its inhabitants* to discover this fact; as only a portion of the rings will be visible in some places, and in the regions near the poles they will appear only like a bright streak in the horizon. They will naturally conclude that the shadows proceed from some body in their firmament; but they will require to make a great variety of observations, to compare them together, and to investigate the doctrine of parallaxes, before they come to the conclusion that the phenomena alluded to are caused by mighty rings which encompass their habitation.

As the diameter of Saturn is ten times the diameter of the earth, it will be comparatively easy for its inhabitants to find the parallaxes, distances, and magnitudes of its different satellites, and likewise of Jupiter and Uranus, which are the only planets visible from Saturn. To those who dwell in its equatorial regions, the motion of the rings around their axes will furnish an accurate measure of time, as well as the diurnal rotation of the planet; and to all places on its surface the periodical revolutions of its different satellites will afford various measures, divisions, and subdivisions of the lapse of duration. The sun will appear from this planet of a size about five times the diameter which Jupiter presents to our view, or about 1-9 or 1-10 part of the diameter of the sun as seen from the earth; but, notwithstanding, there appears no deficiency of light on the surface of Saturn.

Let us, then, suppose two mighty arches in Saturn's nocturnal sky, appearing to the inhabitants of one region like broad semicircles of light extending completely across the heavens, to other regions like large segments of an arch, the highest point of which elevated only twenty or thirty degrees above the horizon, and to the places adjacent to the polar regions as a zone of light hovering in the horizon; let us suppose the distant stars twinkling through the dark space which separates the rings; the sun eclipsed at noon, in one place, by the upper edge of the rings, and in another place by the lower; the brightness of this luminary waxing dimmer and dimmer, and in a few hours hidden by an invisible object, not to appear again till after a lapse of fourteen years; and the inhabitants of this region of shadows occasionally travelling to those countries where the rings are enlightened and the sun is constantly shining: let us suppose one moon, nine times as large in apparent size as ours, suspended in the canopy of heaven; another, three times as large as ours, in another quarter of the sky; a third twice as large; a fourth about the apparent size of our moon, and a fifth, sixth, and seventh of different ap

parent magnitudes; some of them appearing with a crescent, some with a gibbous phase, and others with a full enlightened hemisphere; some rising, some setting; one entering into an eclipse, and another emerging from it; let us suppose such scenes as these, and we may acquire a general idea of the phenomena presented in the heavens of Saturn.

*Scenery of the Heavens in Uranus.*—The orbit of this planet, so far as we know, forms the extreme boundary of the planetary system. Being so far removed from the centre of the system, almost all the other planets and their satellites will be invisible to a spectator placed on this orb. The only planet which will be distinctly visible is Saturn, which will be seen occasionally as a morning and an evening star, and will appear nearly of the same size as to us; but as it will always be seen in the immediate neighbourhood of the sun, it will only be visible at certain distant periods, or intervals of fifteen years, and will appear about as near to the sun as Mercury does when viewed from the earth. Its rings and satellites might occasionally be perceived with such instruments as our best telescopes when it is near the points of its greatest elongation. It is not probable that Jupiter will be visible from this planet on account of its proximity to the sun. If ever it be visible, it will only be for a short time, after periods of six or eight years have elapsed. From Uranus it is likely that the motions of some of the comets will be seen to advantage, and for a considerable length of time, as the motions of these bodies must be comparatively slow in those distant regions. It is not improbable that, in their course from the sun, the motions of some of these bodies may be followed to the extreme point of their trajectories, and their courses traced in their return towards the central luminary; and that they may be visible in the firmament of this planet for months, and even for years together. It is likewise probable that, from Uranus, the parallax of the nearest fixed stars, and, consequently, their *distance*, may be ascertained. For the diameter of its orbit, which is 3,600,000,000 of miles, will form a pretty extensive *base line* for this purpose, and will produce a parallax nineteen times greater than that of the diameter of the earth's annual orbit, which is only 190 millions of miles. But the determination of such a parallax would require a series of observations made at intervals of forty-two years, namely, at two opposite points of the orbit of Uranus, in moving between which it occupies a space of nearly forty-two years.

The most splendid and interesting scenery in the firmament of this planet will be produced by the phases, eclipses, revolutions, and various aspects of its moons. Six of these bodies have been discovered revolving around it, and it is not improbable that several more (perhaps three or four) may be connected with this distant orb, the smallness of which, and their nearness to the planet, may for ever prevent them from being detected by our most powerful instruments. Let us suppose, then, one satellite presenting a surface in the sky eight or ten times larger than our moon; a second five or six times larger; a third three times larger; a fourth twice as large; a fifth about the same size as the moon; a sixth somewhat smaller; and, perhaps, three or four others of different apparent dimensions: let us suppose two or three of these, of different phases, moving along the concave of the sky, at one period four or five of them dispersed through the heavens; one rising above the horizon, one setting, one on the meridian, one towards the north, and another towards the south; at another period five or six of them displaying their lustre in the form of a half moon or a crescent in one quarter of the heavens, and at another time the whole of these moons shining, with full enlightened hemispheres, in one glorious assemblage, and we shall have a faint idea of the beauty, variety, and sublimity of the firmament of Uranus. What is deficient in respect of the invisibility of the other planets is amply compensated by its assemblage of satellites, which illuminate and diversify its nocturnal sky. Although this planet is more than seventeen hundred millions of miles nearer some of the fixed stars than we are, yet those luminaries will not appear sensibly larger, as seen from Uranus, than they do from our globe. For even this immense interval would not subtend an angle of nineteen seconds, or the 1-190 part of a degree, as seen from the nearest star; and, of course, all the constellations will present the same figures and relative aspects as they do to us, with this difference only, that those stars which are near our equator or tropics may be near the poles or polar circles of Uranus. This depends entirely upon the position of its axis of rotation, which is to us unknown. The sun will appear so small from this planet, that its apparent diameter will not exceed 2½ times the apparent diameter of Jupiter; but its light is not so weak as we might be apt to imagine from this circumstance, as is evident from the brightness it exhibits when viewed with a telescope in the nighttime, and likewise from the well-known phenomenon that when the sun is eclipsed to us, so as to have only the *one fortieth* part of its disk left uncovered by the moon, the diminution of light is not very sensible; and it has been frequently noticed that, at the end of the darkness in total eclipses, when the sun's western limb begins to be visible, and seems

no bigger than a thread of fine silver wire, the increase of light is so considerable, and so quickly illuminates all surrounding objects, as to strike the spectators with surprise. But whatever deficiency of light there may be on this planet, we may rest assured, from a consideration of the *wisdom* and benevolence of the Creator, that this deficiency is amply compensated, either by the objects on which it falls being endowed with a strong reflective power, or by the organs of vision being adapted to the light received, or by some other contrivances with which we are unacquainted.

### SCENERY OF THE HEAVENS AS SEEN FROM THE SATELLITES.

*Celestial Scenery of the Moon.*—Although the moon is the nearest body to the earth, and its constant attendant, yet its celestial phenomena will, in a variety of respects, be very different from ours. The earth will appear to be the most splendid orb in its nocturnal sky, and its various phases and relative positions will form a subject of interesting inquiry and contemplation to its inhabitants. It will present the appearance of a globe in the sky *thirteen times larger* than the moon does to us, and will diffuse nearly a corresponding portion of light on the mountains and vales on the lunar surface. As the moon always presents nearly the same side to our view, so the earth will be visible to only one half of the lunar inhabitants. Those who live on the opposite side of the moon, which is never turned towards our globe, will never see the earth in the sky unless they undertake a journey to the opposite hemisphere for this purpose; and those who dwell near the central parts of that hemisphere which is turned from our globe will require to travel more than 1500 miles before they can behold the large globe of the earth suspended in the sky. To all those to whom the earth is visible, it will appear *fixed* and immovable in the same relative point of the sky, or, at least, will appear to have no circular motion round the heavens. To a spectator placed in the middle of the moon's visible hemisphere, the earth will appear directly in the zenith or over head, and will always seem to be fixed very nearly in that position. To a spectator placed in any part of the extremity of that hemisphere, or what seems to us to be the margin of the moon, the earth will appear always nearly in the horizon; and to spectators at intermediate positions the earth will appear at higher or lower elevations above the horizon, according to their distance from the extremities or the central parts of that hemisphere. But, although the earth appears fixed nearly in the same part of the sky, there is a slight variation produced by what is termed the *libration* of the moon (see p. 111,) by which it appears to turn occasionally a small portion of its hemisphere towards the earth. In consequence of this libration the earth will appear now and then to shift its position a little by a kind of vibratory motion. so that those at the extremities of the hemisphere, who see the earth in their horizon, will sometimes see it dip a little below, and at other times rise a little above their horizon. This vibratory motion they will probably be disposed, at first view, to attribute to the earth, which they will naturally consider as a body nearly at rest, but subject to a vibratory movement like that of a pendulum, whereas this apparent vibration proceeds from the moon itself.

The earth is continually shifting its *phases* as seen from the moon. When it is *new moon* to us it is *full moon* to the lunar inhabitants, as the hemisphere of the earth next the moon is then fully enlightened; so that, at the time when the sun is absent, they enjoy the effulgence of a full moon thirteen times larger than ours. When the moon is in the first quarter to us, the earth is in the third quarter to them; and, in every other case, the phases of the earth are exactly opposite to those which the moon presents to us (see p. 111.) The earth passes through all the phases of the moon in the course of a month; but the *progress* of these phases will be more regularly and accurately perceived than that of the moon's phases are by us. When it is night in the moon, and the nights there are a fortnight long, the inhabitants see at first only a small part of the earth enlightened, like a slender crescent; then a larger and a larger portion, till at length it becomes entirely luminous. During the whole of these changes the earth is every moment visible, and apparently fixed in the same immovable position; and as there are no clouds in the lunar atmosphere, the view of the earth and of the variation of its phases will never be interrupted; whereas these changes in the moon are visible to us only from one night to another, and, by the interposition of clouds, the moon is frequently hidden from our view for seven or eight days together. By means of the light thus diffused by the earth upon the moon, it so happens that the side of the moon next the earth is never in darkness; for, when the sun is absent, the earth shines in the firmament with a greater or less degree of splendour; but when the sun is absent from the other hemisphere, the inhabitants have no light but what is derived from the stars and planets. It is probable, however, that the light of these luminaries is more brilliant as seen from the moon than from the earth, as the lunar atmosphere is more pure and transparent than that of the earth, and as no clouds or dense vapours

exist in it to intercept the rays of those distant orbs; and the stars and planets will constantly shine in the firmament of that hemisphere of the moon with undiminished lustre. Perhaps, too, there may be some arrangement for providing additional light to that hemisphere in the absence of the sun, either by the coruscations of some phosphoric substance, or by something analogous to our aurora borealis.

Whether the earth will throw as much light upon the moon, *in proportion to its size*, as the moon diffuses upon the earth, is somewhat doubtful. I am disposed to think that the greater part of the surface of the terraqueous globe will not reflect so much light, in proportion to its bulk, as the general surface of the moon; for, as the greater part of the earth is covered with water, and as water absorbs a considerable portion of the rays of light, the seas and ocean will present a more dark and sombre aspect than any part of the lunar orb presents to us; but it is highly probable that the continents and islands will exhibit a lustre nearly equal to that of the mountainous regions of the moon.

Although the earth will seem nearly fixed in one position, yet, *its rotation round its axis will be distinctly perceptible*, and will present a variety of different appearances. Europe, Asia, Africa, and America, will present themselves one after another in different shapes, nearly as they are represented on our maps and globes; and the regions near our poles, which we have never yet had it in our power to explore, will be distinctly seen by the lunarians, who will be enabled to determine whether they chiefly consist of land or of water. The several continents, seas, islands, lakes, peninsulas, plains, and mountain ranges, will appear like so many spots, of different forms and degrees of brightness, moving over its surface. When the Pacific Ocean, which occupies nearly half the globe, is presented to view, the great body of the earth will assume a dusky or sombre aspect, except towards the north, the north-east, and north-west; and the islands connected with this ocean will exhibit the appearance of small lucid spots on a dark ground. But when the eastern continent turns round to view, the earth (especially its northern parts) will appear to shine with a greater degree of lustre. These appearances will be diversified by the numerous strata of clouds which are continually carried by the winds over different regions, and will occasionally intercept their view of certain parts of the continents and seas, or render their appearance more obscure at one time than at another. It is likewise probable that the occasional storms in tropical climates, and the changes produced in different countries by summer and winter, will cause the earth to present a diversity of aspect to the inhabitants of the moon. The bands of ice which surround the poles will alternately exhibit a kind of lucid circle, while the verdant plains will appear of a different colour and assume a milder aspect. By means of these different spots, the lunarians will be enabled to determine the exact period of the earth's rotation, as we determine that of the sun by the appearance and disappearance of the spots on its surface. And as the period of the earth's rotation never varies, it may serve as a clock or dial for the exact measure of time; and the lesser divisions of this period may be ascertained by the appearance on the margin or the central parts of the earth's hemisphere of certain seas, continents, or large islands, which will constantly appear on certain parts of the earth's disk at regular intervals of time. Through telescopes such as ours, the variegated aspect of the earth in its diurnal motion would present to us, were we placed on the moon, a novel and most interesting appearance.

The apparent diurnal motions of the sun, the planets, and the stars, will appear much slower, and somewhat different in several respects from what they do to us. When the sun rises in their eastern horizon, his progress through the heavens will be so slow that it will require more than seven of our days before he comes to the meridian, and the same time before he descends to their western horizon; for the days and nights of the moon are nearly fifteen days each, and they are nearly of an equal length on all parts of its surface, as its axis is nearly perpendicular to the ecliptic, and, consequently, the sun never removes to any great distance from the equator. During the day the earth will appear like a faint cloudy orb, always in the same position; and during night the stars and planets will be visible, *without interruption*, for fifteen days, and will be seen moving gradually during that time from the eastern to the western horizon. Though the earth will always be seen in the same point of the sky both by day and night, yet it will appear to be constantly shifting its position with respect to the planets and the stars, which will appear to be regularly moving from the east to the west of it, and some of them will occasionally be hidden or suffer an *occultation* for three or four hours behind its body. The sun, planets, and fixed stars will appear exactly of the same apparent magnitudes as they do from the earth; but as the poles of the moon are directed to points of the heavens different from those to which the poles of the earth are directed, the pole-stars in the lunar firmament, and the stars which mark its equator and parallels, will all be different from ours; so that the stars, in

their apparent diurnal revolutions, will appear to describe circles different from those which they describe in our sky. The *inferior* planets Mercury and Venus will generally be seen in the neighbourhood of the sun, as they are from the earth; but they will be more distinctly perceived, and be visible for a much longer period of time after sunset than they are from our globe. This is owing, first, to the transparency of the lunar atmosphere, and the absence of dense vapours near the horizon, which, in our case, prevent any distinct observations of the celestial bodies when at a low altitude; and, secondly, to the slow apparent diurnal motion of these bodies. When Mercury is near its greatest elongation, it will remain above the horizon more than thirty hours after the sun has set, and, consequently, will be visible for a much longer time in succession than it is to us. When Venus is near its greatest elongation, it will be seen, without intermission, either as a morning or an evening star, for a space of time equal to more than three of our days. The *superior* planets, as with us, will be seen in different parts of the heavens, and occasionally in opposition to the sun; but they will appear to be continually shifting their positions with respect to the earth, and in the course of fifteen days will be seen in the very opposite quarter of the heavens, and in other fifteen days will be again in conjunction with the earth; and nearly the same appearances will be observed in reference to the other planets, but the periodic times of their conjunctions with the earth and oppositions to it will be somewhat different, owing to the difference of their velocities in their annual revolutions.

The *eclipses of the sun* which happen to the lunarians will be more striking, and total darkness will continue for a much longer time than with us. When a total eclipse of the *moon* happens to us, there will be a total eclipse of the *sun* to the lunarians. At that time the dark side of the earth is completely turned towards the moon, and the sun will appear to pass gradually behind the earth till it entirely disappears. The time of the continuance of *total darkness* in central eclipses will be nearly two hours; and, of course, a total eclipse of the sun will be a far more striking and impressive phenomenon to the inhabitants of the moon than to us. A complete darkness will ensue immediately after the body of the sun is hidden, and the stars and planets will be as clearly seen as at midnight. When a *partial* eclipse of the moon happens to us, all that portion of the moon's surface over which the shadow of the earth passes will suffer a *total* eclipse of the sun during the period of its continuance. On other parts of the moon's surface there will be a *partial* eclipse of the sun, and to those who are beyond the range of the earth's shadow no eclipse will appear. When an eclipse of the *sun* happens to us, the lunarians will behold a dark spot, with a penumbra or fainter shades around it, moving across the disk of the earth, which then appears a full enlightened hemisphere, excepting the obscurity caused by the progress of the shadow. The inhabitants on the other hemisphere of the moon can never experience a solar eclipse, as the earth can never interpose between the sun and any part of that hemisphere, so that they will only know of such phenomena by report, unless they undertake a journey for the purpose of observing them.

The study of astronomy in the moon will, on the whole, be more difficult and complex than to us on the earth. The phenomena exhibited by the earth will be the most difficult to explain. The lunarians, at first view, will be apt to imagine that the earth is a quiescent body in their firmament, because it appears in the same point of the sky, and that the other heavenly orbs revolve around it. It will require numerous observations of the apparent motions of the sun, the earth, the planets, and the stars, and numerous trains of reasoning respecting the phenomena they exhibit, before they are convinced that the globe on which they dwell really moves round the earth, and that both of them move, in a certain period, around the sun. If they are endowed with no higher powers than man, or if they are as foolish and contumacious as the great bulk of mankind, it will be more difficult to convince them of the true system of the world than it has been for our astronomers to convince a certain portion of our community that the earth turns round its axis, and performs a revolution round the sun. They will naturally think, as we did formerly, that their habitation is in a quiescent state in the centre of the universe, and that all the other bodies in the heavens, except the earth, revolve around it; and the singular phenomena which our globe exhibits in their sky, with its diversified aspect, its diurnal rotation, and occasional *vibrations*, will puzzle them not a little in attempting to find out a proper explanation It will be somewhat difficult for them to ascertain the exact length of their year, or the time of their revolution round the sun. There are only two ways by which we can conceive they will be enabled to determine this point: 1. By observing when either of the poles of the earth begins to be enlightened and the other pole to disappear, which is always at the time of our equinoxes. 2. By observing the course of the sun among the stars, and endeavouring to ascertain when he returns to the same rela-

ave position in reference to any of these orbs. The length of the lunar year is about the same as ours, but different as to the number of days, the lunarians having only 12 7-19 days in their year, every day and night being as long as 29½ of ours. On the other hand, the lunar astronomers will enjoy some advantages in making celestial observations which we do not possess. Those who live on the side next the earth will be enabled to determine the *longitude* of places on the lunar surface with as much ease as we find the *latitude* of places on our globe. For as the earth keeps constantly over one meridian of the moon (or very nearly so,) the east and west distances of places from that meridian may be readily found, by taking the altitude of the earth above the horizon, or its distance from the zenith, on the same principle as we obtain the latitude of a place by taking the altitude of the pole-star, or the height of the equator above the horizon. The lunar astronomers will likewise possess advantages superior to ours in the purity of their atmosphere, and the greater degree of brilliancy with which the heavenly bodies will appear; and, in particular, they enjoy a singular advantage above a terrestrial astronomer in the *length of their nights*, which gives them an opportunity of contemplating the heavenly bodies, particularly Mercury and Venus, and tracing their motions and aspects for a length of time without intermission.

Such are some of the peculiar phenomena of the heavens as beheld from the moon. However different these phenomena may appear from those which are beheld in our terrestrial firmament, they are all owing to the following circumstances: that the moon moves round the earth as the more immediate centre of its motion; that it turns always the same side to the earth, and, consequently, it moves round its axis in the same time in which it moves round the earth. These slight differences in the motions and relative positions of the earth and moon are the principal causes of all the peculiar aspects of the lunar firmament which we have now described. And this consideration shows us how the Creator may, by the slighest changes in the positions and arrangements of the celestial orbs, produce an indefinite variety of scenery throughout the universe, so that no world or system of worlds shall present the same scenery and phenomena as another. And so far as our knowledge and observation extends, this appears to be one of the grand principles of the Divine arrangements throughout the system of Creation, which will be still more apparent from the sketches I am now about to give of the phenomena presented from the surfaces of the satellites connected with the other planets.

*The Scenery of the Heavens from the Satellites of Jupiter.*—The scenery of the firmament as beheld from the satellites of this planet will bear a certain analogy to what we have now described in relation to the moon, but it will be much more diversified and resplendent. The most striking and glorious object in the firmament of the *first satellite* is the planet itself. The distance of this satellite from the centre of Jupiter being only about three diameters of that body, it will appear in the heavens like an immense globe, above thirteen hundred times larger than the apparent size of our moon, and will occupy a considerable portion of the celestial hemisphere. To those who live in the middle of the hemisphere of this satellite, opposite to Jupiter, this vast globe will appear in the zenith, filling a large portion of the sky directly above them, equal to 19 degrees of a great circle, so that nine or ten of such bodies would reach from one side of the heavens to another. To those in other situations it will appear at different elevations above the horizon, according to their distances from the central parts of that hemisphere. This huge globe, in the course of twenty-one hours, will exhibit a crescent, a half moon, a gibbous phase, and a full enlightened hemisphere, so that its appearance will be perpetually changing. When it shines with a full face, it will exhibit a most glorious appearance: it will reflect an immense quantity of light upon the satellite, and all the varieties on its surface will be beautifully perceived. In the daytime it will present a cloudy appearance, continually changing its form, and when its dark side is turned to the satellite it will probably become invisible; but it will never be altogether invisible beyond two or three hours at a time, till its enlightened crescent again begins to appear. We find by the telescope that the surface of Jupiter is diversified with a variety of belts, which frequently change their appearance, and sometimes by bright and dark spots. Now all the varieties on its surface, and the changes which may take place in its atmosphere, will be pretty distinctly seen from the surface of this satellite; and as Jupiter turns round its axis in the space of less than ten hours, every hour will present a new scene upon its surface. This expansive and variegated surface of Jupiter, its diurnal rotation, and its rapid change of phases, will therefore form a most wonderful and interesting spectacle to the inhabitants of this satellite.

The three other satellites will likewise increase the variety and the lustre of its firmament. The second satellite, in its course round Jupiter, will frequently come within 160,000 miles of the first, which is its nearest approach to it; at which time the satellite will appear with a face nearly three times as large

as our moon. At other times it will be 680,-000 miles distant, and will appear more than sixteen times smaller than in the former position. At the time when Jupiter presents its dark hemisphere to the first satellite, if the second satellite be then at its nearest distance, or in opposition to the sun, it will shine with a full enlightened hemisphere upon the first satellite. At other times it will assume a half moon, a crescent, or a gibbous phase; and these phases will not only be rapidly changing, but the apparent magnitude of the satellite will likewise be rapidly increasing or diminishing. While at one period it shines with a large and full-enlightened face, in the course of two or three of our days it will appear as a slender crescent, and more than twelve or sixteen times less in apparent diameter than before. The third and fourth satellites will exhibit phenomena somewhat similar; but as their distance is greater than that of the second, their apparent magnitudes will be smaller, and the changes of their phases will be less frequent, in proportion to the slowness of their motions and the length of the periods of their revolutions. The eclipses of the sun, which so frequently happen to the first satellite from the interposition of the body of Jupiter, will form very interesting and impressive phenomena. Every forty-two hours this satellite suffers a solar eclipse for the space of more than two hours; and it is highly probable that it is chiefly at such times that the starry firmament appears in all its splendour, and affords its inhabitants an opportunity of tracing the motions and contemplating the phenomena of the distant bodies of the universe; for at other times the blaze of reflected light from the body of Jupiter and from the other satellites will, in all probability, prevent the greater part of the fixed stars from being distinctly perceived; so that these eclipses, instead of being an evil or a cause of annoyance to the inhabitants, will increase their enjoyment, will add to the variety of their celestial scenery, and open to them prospects of the grandeur of the starry firmament and the distant regions of creation.

What has been now stated in reference to the first satellite may also be applied in general to the other three satellites, with this difference, that Jupiter will appear of a different apparent magnitude from each satellite; and the motions, magnitudes, and aspects of the other satellites will likewise be somewhat different. In each satellite the great globe of Jupiter, suspended motionless in the sky, will be the most conspicuous object in the heavens. To the *second* satellite this globe will appear about 470 times larger than our moon; to the *third* 180 times; and to the *fourth* about 80 times the apparent size of the full moon. But each satellite will have certain other phenomena *peculiar to itself*, which it would be too tedious to describe. To all of them the occultations of the other satellites by the body of Jupiter; their eclipses by falling into its shadow; the varieties on its surface, caused by its diurnal rotation; the shadows of the satellites passing like dark spots across its disk; the transits of the satellites themselves, like full moons crossing the orb of Jupiter; the diversified phenomena of eclipses, some of them happening when the satellite is like a crescent or half moon, and some of them when it appears as a full enlightened hemisphere, and various other circumstances, will afford an indefinite variety of celestial phenomena; and scarcely a single day will pass in which some of these phenomena are not observed. The length of the day is different in each satellite. In the first satellite, the length of the day and night is 42 hours 27 minutes; in the second, 3 days, 13 hours; in the third, 7 days, 3½ hours; and in the fourth, 16 days, 16½ hours. The starry heavens will therefore appear to make a revolution round each satellite in these respective times. The other satellites will also appear to make a diurnal revolution, but in periods of time somewhat different. The variety of motions, and other phenomena to which we have now alluded, and particularly the rotation of Jupiter and the variation of its phases, will afford various accurate measures of time to all the satellites. The following figure contains a rude of sketch of a portion of the firmament as it will appear from one of the satellites of Jupiter.

Fig. 111.

In this figure, suppose the larger circle at the top to represent one of the satellites as seen in the firmament of the fourth satellite, and suppose it appears with a surface twice the size of our moon; Jupiter would require to be double the size here represented, and

more than fifteen times larger to represent its comparative size as viewed from the *first* satellite. The larger circle represents Jupiter when exhibiting a gibbous phase to the satellite; the three other figures are the other satellites under different phases.

*Celestial Scenery of the Satellites of Saturn.*—What has been stated above in relation to Jupiter's satellites will apply, in part, to those of Saturn. But the satellites of this planet have likewise celestial scenery *peculiar to themselves*, and the scenes presented to one satellite are, in some respects, different from those presented to all the rest. One of the most singular phenomena in their firmament is the diversified appearance of the body of Saturn and that of its rings, which will be beheld in their sky under a great variety of aspects. To describe all the variety of phenomena peculiar to each satellite connected with Saturn would almost require a separate treatise, and therefore I shall state only two or three prominent facts in relation to the *first* and *seventh*, or the innermost and outermost satellites. The first satellite, being only 80,000 miles distant from the *surface* of Saturn, and only 18,000 miles from the outer edge of the rings, the globe of Saturn and its stupendous rings must present a very august and striking appearance in its nocturnal firmament. The hemisphere of Saturn contains an area more than 1300 times larger than that of our moon; consequently, if the first satellite were placed at the same distance from Saturn as our moon, the surface of that planet would appear, from the satellite, 1300 times larger than the moon does to us. But the satellite is only 120,000 miles from the centre of Saturn, or half the distance of the moon from the centre of the earth; therefore Saturn will appear four times larger, or 5200 times greater, as seen from this satellite, than the moon when viewed from the earth. The moon occupies only the 1-90,000 part of our celestial hemisphere, but the globe of Saturn will fill the *one seventeenth part* of the visible firmament of its first satellite; and if we take the extent of the rings into account, they will occupy a space two or three times greater; so that the planet and its rings will present a most grand and magnificent object in the canopy of heaven, of which we can form only a very faint conception. It is not likely that more than one half of the globe of Saturn will be visible from this satellite on account of the interposition of the rings; and as it moves in an orbit which is nearly parallel with the plane of the rings, the surfaces of these rings will be seen in a very *oblique direction;* but still they will exhibit a very resplendent appearance. When the *edge* of the exterior ring is opposite to the satellite, and enlightened by the sun, it will present a large arch of light in the heavens on each side of the planet, above which will appear half the hemisphere of Saturn. If the satellite turn round its axis in the same time in which it revolves round the planet, as is probable, Saturn and its rings will appear stationary in the heavens, and the planet will present to the inhabitants of the satellite a variety of phases, such as a half moon and a crescent, besides the variety of objects which will appear on the surface of Saturn during its rotation on its axis. The rings will likewise appear to vary their aspect during every revolution, besides the variety of objects they will present during their rotation. At one time they will exhibit large and broad luminous arches; at another time they will appear as narrow streaks of light; and at another they will appear like dark belts across the disk of Saturn. And as this satellite moves round the planet in the course of twenty-two and a half hours, these appearances will be changing almost every hour. The appearances of the six other satellites, continually varying their phases, their apparent magnitudes, and their relative aspects; their positions in respect to the body of Saturn and its rings; their occultations by the interposition both of the rings and the planet, and the eclipses to which they are frequently subjected, will produce a diversity of phenomena and a grandeur unexampled in the case of any other moving bodies in our system. The second satellite, when in opposition, or at its nearest position to the first, will be only thirty thousand miles distant; and although its real size is not greater than our moon, it will present a surface sixty-four times larger than the full moon does in our sky. It will appear in all the phases of the moon in the course of less than thirty-six hours, and will be continually changing its apparent magnitude, on account of its removing further from or nearer to the first satellite. The third satellite* will appear nearly half as large, as it is only seventy thousand miles distant at its nearest approach; and will present nearly the same varieties as the other. All the other satellites will appear smaller in proportion to their distance from the orbit of the first; but they will all appear much larger than our moon, except the seventh, or outermost satellite, which will appear considerably smaller. Perhaps the sixth satellite from Saturn will not appear larger than our moon.

The seventh or outermost satellite, which is reckoned among the largest, will have a scenery in its sky somewhat different from that of the first. As its orbit is materially inclined to the rings, its inhabitants will have

* Here the satellites are distinguished *according to the order of their distances from Saturn.*

a more ample prospect of these rings and of the body of Saturn than several of the other satellites, although these objects are beheld at a greater distance, and, consequently, will not fill so large a portion of its sky. Their appearance, however, will not be destitute of splendour; for this satellite is 400 times nearer Saturn than we are, and the body of this planet will appear sixteen times larger than the moon to us, and its rings will occupy a space proportionably more expansive. The phases of Saturn and its rings, and the various changes of aspect which they assume, will be more distinctly perceptible, though on a smaller scale, than from some of the interior satellites; for the whole body of the planet, as well as the rings, will in most cases appear full in view. The other six satellites will be seen in all the different phases and aspects above described, and they will never appear to recede to any great distance from the body of Saturn; but will appear first on one side and then on another, and sometimes either above or below the planet, as Mercury and Venus appear to us in respect to the sun, and, consequently, that portion of the heavens in which Saturn appears will present a most splendid appearance. In this respect the relative positions of the satellites, as seen from the outermost, will be different from their aspects and positions as viewed from the innermost satellite, where they will sometimes appear in regions of the sky directly opposite to Saturn. All the other satellites of this planet will have phenomena *peculiar to themselves* in their respective firmaments, and in all of them these phenomena will be exhibited on a scale of grandeur and magnificence. But to enter into details in reference to each satellite might prove tedious to the general reader.

Let us, then, conceive a firmament in which is suspended a globe five thousand times larger than the apparent size of our moon; let us conceive luminous arches, still more expansive, surrounding this globe; let us conceive six moons of different apparent magnitudes, some of them sixty times larger in apparent size than ours; let us conceive, further, all these magnificent bodies sometimes appearing in one part of the heavens and sometimes in another, changing their phases and apparent magnitudes and distances from each other every hour; appearing sometimes like a large crescent, sometimes like a small, sometimes shining with a full enlightened face, and sometimes suffering a total eclipse; sometimes hidden behind the large body of the planet, and sometimes crossing its disk with a rapid motion, like a circular shadow; let us suppose these and many other diversified phenomena presenting themselves with unceasing variety in the canopy of heaven, and we shall have some faint idea of the grandeur of the firmament as seen from some of the satellites of Saturn.

No delineations, except on a very large scale, could convey any tolerable idea of the objects now described. Fig. 112 exhibits a

Fig. 112.

rude idea of the firmament as viewed from the first or second satellite of Saturn; but the body of Saturn and the ring should be eight or ten times larger in proportion to the size of the moons or satellites here represented. As the orbits of the inner satellites are nearly on the same plane as the rings, they will appear in an oblique position, and it is questionable whether the division between the rings will be distinctly visible. The opposite part of the ring, or that which is most distant from the satellite, will appear smaller than the side which is nearest it; and only one half of the body of Saturn will be seen, the other half being hidden, either in whole or in part, by the ring.

Fig. 113 represents the firmament of the

Fig. 113.

seventh or outermost satellite. As its orbit is considerably inclined to the plane of the ring, the whole body of the planet will frequently be seen within the rings, which will appear as ovals around it. The six other satellites will appear in the vicinity of Saturn and its rings,

none of them ever removing to any considerable distance from the edge of the rings, and some of them may occasionally be seen moving in the open space between the planet and the rings. In this figure Saturn and the rings should be considerably larger in proportion to the moons than they are here represented.

*Celestial Scenery as viewed from the* RINGS *of Saturn.*—Supposing the rings to be inhabited, which there is as much reason to believe that the planet itself is a habitable globe, it is probable that there is a greater diversity of celestial scenery and of sublime objects presented to view than any we have yet described. There will be at least six varieties of celestial scenery, according as the spectator is placed on different parts of the rings. One variety of scene will be exhibited from the *exterior* edge of the outer ring; a second variety from the *interior* edge of the inner ring; a third variety from the interior edge of the *outer* ring; a fourth from the exterior edge of the *inner* ring; a fifth from the *sides* of the rings enlightened by the sun; and a sixth variety from the opposite sides, which are turned away from the sun, and enjoy, for a time, only the reflected light from the satellites. To describe all these varieties in a minute detail would be tedious, and at the same time unsatisfactory, without the aid of diagrams and figures on a very enlarged scale, and therefore I shall chiefly confine myself to a general description of one of these celestial views.

Those who live on the sides of the rings will behold the one half of the hemisphere of Saturn, which will fill, perhaps, the one fifth or the one sixth part of their celestial hemisphere, while the other portions of the planet will be hidden by the interposition of the rings. Those who are near the inner edge of the interior ring are only thirty thousand miles from the surface of Saturn, and consequently all the varieties upon its surface will be distinctly perceived. Those near the outer edge of the exterior ring are about sixty thousand miles distant from the planet, which will consequently appear to them four times less in size than to the former; but being only eighteen thousand miles from the first satellite at the time of its opposition to Saturn, that satellite will present an object more than three hundred and fifty times larger than our moon, which will rapidly assume different phases, and will be continually varying in its apparent magnitude; and at its greatest distance beyond the opposite side of the rings it will appear at least 170 times less than when in the nearest point of its orbit; and all the intermediate varieties of magnitude and aspect will be accomplished within less than two days. So that this satellite will be continually changing its apparent size, from an object two or three times the apparent bulk of our moon to one 350 times greater. The same may be affirmed in respect to the other six satellites, with this exception, that they will appear of a smaller magnitude, and the periodic times of their phases and the changes in apparent magnitude will be different.

Another object which will diversify the firmament of those who are on one of the sides of the rings is the opposite portions of the rings themselves. These will appear proceeding from each side of the planet like large broad arches of light, each of them somewhat less than a quadrant, and will fill a very large portion of the sky, so that the inhabitants of the same world will behold a portion of their own habitation forming a conspicuous part of their celestial canopy, and, at first view, may imagine that it forms a celestial object with which they have no immediate connexion. Were they to travel to the opposite part of the ring, they would see the habitation they had left suspended in the firmament, without being aware that the spot which they left forms a portion of the phenomenon they behold. As the rings revolve round the planet, and the planet revolves round its axis, the different parts of the surface of the planet will present a different aspect, and its variety of scenery will successively be presented to the view. The eclipses of the sun and of the satellites, by the interposition of the body of Saturn and of the opposite sides of the rings, will produce a variety of striking phenomena, which will be diversified almost every hour.

From the dark side of the rings, which are turned away from the sun for fifteen years, a great variety of interesting phenomena will likewise be presented; and, during this period, the aspect of the firmament will in all probability be most vivid and striking. This portion of the rings will not be in absolute darkness during the absence of the sun, for some of the seven satellites will always be shining upon it; sometimes three, sometimes four, and sometimes all the seven, in one bright assemblage. It is probable, too, that the planet, like a large slender crescent, will occasionally diffuse a mild splendour; and, in the occasional absence of these, the fixed stars will display their radiance in the heavens, which will be the principal opportunity afforded for studying and contemplating these remote luminaries. Those who are on the outermost ring will behold the other ring, and the opposite parts of their own, like vast arches in the heavens; and although only 2800 miles intervene between the two rings, that space may be as impassable as is the space which intervenes between us and the moon.

If the two rings have a rotation round

Saturn in different periods of time, as is most probable, it will add a considerable variety to the scenery exhibited by the different objects which will successively appear in the course of the rotation.

The numerous splendid objects displayed in the heavens, as seen from these rings, would afford a grand and diversified field for telescopic observations, surpassing in variety and sublimity whatever is displayed in any other

Fig. 114.

region of the solar system; by which some of the objects might be contemplated as if they were placed within the distance of forty or fifty miles.

The preceding figure (114) represents a view of the firmament from one of the sides of the rings, in which is seen half of the hemisphere of Saturn, with a portion of the opposite sides of the rings projecting, as it were, from each side of the planet, the central part being hidden by the interposition of its body. From the inner edge of the interior ring the whole hemisphere of Saturn will be visible. The body of Saturn and the rings should be at least twenty times larger than here represented, so as to be proportionate to the apparent size of the satellites.

*Celestial Scenery from the Satellites of Uranus.*—After what we have stated respecting the satellites of Jupiter, it would be needless to enter into detail respecting the celestial views from the satellites of this planet, as they will bear a striking analogy to those of the moons of Jupiter; but the firmament of each satellite of Uranus will be more diversified than that of any of the satellites of Jupiter, as there are six satellites connected with this planet, and probably three or four more which lie beyond the reach of our telescopes. From its first satellite the body of Uranus will appear nearly three hundred times larger than the apparent size of the moon in our sky, and, consequently, will appear a very grand and magnificent object in its firmament, while the other five moons, in different phases and positions, will serve both to illuminate its surface and to diversify the scenery of the heavens. To the second satellite Uranus will appear about one hundred and eighty times larger than the moon to us; and to the other satellites it will present a smaller surface in proportion to their distance. Each satellite will have its own peculiarity of celestial phenomena; but after what we have already stated in the preceding descriptions, it would be inexpedient to enter into details. I shall therefore conclude these descriptions with the following remarks:

1. In the preceding descriptions, the *apparent magnitudes* of Jupiter, Saturn, and Uranus, as seen from the satellites, and the apparent magnitudes of the satellites as seen from each other, are only approximations to the truth, so as to convey a *general idea* of the scenes displayed in their respective firmaments; perfect accuracy being of no importance in such descriptions. 2. The variety of celestial phenomena in the firmaments of these bodies is much greater than we have described. Were we to enter into minute details in relation to such phenomena, it would require a volume of considerable size to contain the descriptions; for in the system of Saturn itself there is more variety of phenomena than in all the other parts of the planetary system. 3. Machinery would be requisite in order to convey clear ideas of some of the views alluded to in the preceding descriptions, particularly in relation to the rings and satellites of Saturn, in which the proportional distances and magnitudes of the respective bodies would require to be accurately represented. An instrument of considerable size and complication of machinery would be requisite for exhibiting all the phenomena connected with Saturn; and one of the principal difficulties would be to produce a diurnal rotation of the rings round Saturn, while at the same time they had no immediate connexion with it, and while their *thickness* was no greater in proportion to their breadth than what is found in nature, which is only about the one three hundredth part of the breadth of the two rings, including the empty space between them. 4. The diversity of celestial scenery to which we have alluded is an evidence of the *infinite variety* which exists throughout the universe, and shows us by what apparently simple means this variety is produced. We are thus led to conclude, that among all the systems and worlds dispersed throughout boundless space, there is no one department of creation exactly resembling another. This is likewise exemplified in the boundless variety exhibited in our world, in

the animal, vegetable, and mineral kingdoms. 5. The alternations of light and darkness, and the frequent eclipses of the celestial luminaries which happen among the bodies connected with Jupiter, Saturn, and Uranus, so far from being inconveniences and evils, may be considered as blessings and enjoyments; for it is only or chiefly when their inhabitants are deprived of the direct light of the sun, or its reflection from the satellites, that the starry heavens will appear in all their glory; and as the interval in which they are thus deprived of light is short, and as it adds to the variety of the celestial scene, it must be productive of pleasure and enjoyment. 6. The same planets will be seen in the firmaments of the satellites as in those of their primaries; but they will be seldom visible on account of the large portion of reflected light which will be diffused throughout their sky, except in those cases when their nocturnal luminaries suffer an occultation or a total eclipse. The bodies more immediately connected with their own system will form the chief objects of their attention and contemplation, and will appear more interesting and magnificent than any phenomena connected with more distant worlds. 7. On all the satellites, and particularly on the rings of Saturn, it will be more difficult to ascertain the true system of the universe than in any other point of the solar system. I have already alluded to the difficulty of determining the true system of the world as observed from the moon: but it will be still more difficult in the case of observers placed on the rings or satellites of Saturn. The numerous bodies which are seen every hour shifting their aspects and positions, the apparent complication of motions which they will exhibit, their phases, eclipses, and rapid diminution of apparent size, combined with the apparent diurnal revolution of the heavens and of all the bodies in their firmament, will require numerous and accurate observations, and powers of intellect superior to those of man, in order to determine with precision their place in the solar system and the true theory of the universe.

## CHAPTER IX.

*On the Doctrine of a plurality of Worlds, with an Illustration of some of the Arguments by which it may be supported.*

In the preceding descriptions of the facts connected with the bodies which compose the planetary system, and of the celestial scenery displayed in their respective firmaments, I have assumed the position that they are all peopled with intellectual beings. This is a conclusion to which the mind is almost necessarily led, when once it admits the facts which have been ascertained by modern astronomers. It requires, however, a minute knowledge of the whole scenery and circumstances connected with the planetary system before this truth comes home to the understanding with full conviction. As in the preceding pages I have stated, with some degree of minuteness, the prominent facts connected with all the bodies of the solar system (except comets,) so far as they are yet known, the way is now prepared for bringing forward a few arguments founded on these facts, which will require less extensive illustrations than if I had attempted to discuss this topic without the previous descriptions. It may be proper, however, to state, that in this volume I propose to bring forward *only a few* of those arguments or considerations by which the position announced above may be corroborated and supported, leaving the discussion of the remaining arguments to another volume, in which the other portions of the scenery of the heavens will be described. This is rendered almost indispensable on account of the size to which the present volume has already swelled.

### Section I.

The first argument I shall adduce in support of the doctrine of a plurality of worlds is, that *there are bodies in the planetary system of such* MAGNITUDES *as to afford ample scope for the abodes of myriads of inhabitants.*

This position has been amply illustrated in the preceding parts of this volume, particularly in chapter iii. From the statements contained in chapter vi., it appears that the whole planetary bodies, exclusive of the sun, comprehend an area of more than *seventy-eight thousand millions of square miles*, which is *three hundred and ninety-seven times* the area of our globe; so that the surfaces of all the planets and their satellites are equal, in point of space, to 397 worlds such as ours. But as the greater part of our globe is covered with water, and, consequently, is unfit for the permanent residence of rational beings, and as we have no reason to believe that the other planets have such a proportion of water on their surface, if we compare the

habitable parts of the earth with the extent of surface on the planets, we shall find that they contain *one thousand five hundred and ninety-five times* the area of all that portion of our globe which can be inhabited by human beings. If we take into consideration the *solid contents* of these globes, we find that they are more than *two thousand four hundred and eighty times* the bulk of our globe; and the number of inhabitants they would contain, at the rate of England's population, is no less than 21,895,000,000,000, or nearly *twenty-two billions*, which is more than *twenty-seven thousand times* the present population of our globe. In other words, the extent of surface on all the planets, their rings and satellites, in respect of space for population, is equivalent to 27,000 worlds such as ours in its present state.

Now, can we for a moment imagine that the vast extent of surface on such magnificent globes is a scene of barrenness and desolation; where eternal silence and solitude have prevailed, and will for ever prevail; where no sound is heard throughout all their expansive regions; where nothing appears but interminable desarts, diversified with frightful precipices and gloomy caverns; where no vegetable or mineral beauties adorn the landscape; where no trace of rational intelligences is to be found throughout all their wastes and wilds; and where no thanksgivings, nor melody, nor grateful adorations ascend to the Ruler of the skies? To suppose that such is the state of these capacious globes would exhibit a most gloomy and distorted view of the character and attributes of the Creator. It would represent him as exerting his creating power to no purpose; and as acting in a different, and even in an *opposite character*, in different parts of his dominions; as displaying wisdom in one part of his creation, and an opposite attribute in another. For, so far as we are able to penetrate, it appears demonstrable that matter exists chiefly, if not *solely*, for the sake of sensitive and intellectual beings; either to serve the purpose of gratifying the senses, or of affording a medium of thought to the mental faculty, or of exhibiting to the mind a sensible display of the existence and perfections of the supreme Intelligence. And if it serve such purposes in this part of the creation which we occupy, reason says that it must serve similar purposes in other regions of the universe. How incongruous would it be to maintain that matter serves such purposes in our terrestrial sphere, and nowhere else throughout the range of the planetary system? In other words, that it is useful to sensitive existences within the compass of the *one four hundredth part* of that system, but serves no useful or rational purpose in the other three hundred and ninety-nine parts; for the area of the earth, as above stated, is only about the one four hundredth part of the area of all the other planets. Such a conclusion can never be admitted in consistency with those perfections which both natural and revealed religion attribute to the Deity. If matter was not created merely for itself, but for the enjoyment of a superior nature, then it necessarily follows, that *wherever matter exists, that nobler nature*, whether sensitive or intellectual, *for whose sake it was created, must likewise exist* throughout some portions of its extent. To replenish one comparatively little globe with sensitive and rational inhabitants, and to leave several hundreds empty, desolate, and useless, is the perfect reverse of art and contrivance, and altogether incompatible with the conceptions we ought to form of Him who is "the only wise God," and who is declared to have displayed himself, in all his operations, as "wonderful in counsel and excellent in working."

In accordance with this sentiment, we find the inspired writers, when speaking in the name of Jehovah, admitting the validity of such reasoning. "Thus saith Jehovah that created the heavens; God himself that formed the earth and made it: he hath established it; HE CREATED IT NOT IN VAIN; HE FORMED IT TO BE INHABITED. I am Jehovah, and there is none else."* Here it is plainly and pointedly declared, that to create the earth without the design of its being inhabited would have been a piece of folly inconsistent with the perfections of Him whose intelligence and wisdom are displayed throughout all his works To have left it empty and useless would have been "to create it in vain." It would neither have contributed to the enjoyment of intellectual beings, nor served as a manifestation of the intelligence, wisdom, and beneficence of its Creator. This passage likewise intimates that it is the ultimate design of Jehovah tha this world shall, ere long, be fully peopled with inhabitants, and that its forests and desolate wastes shall, in future ages, be transformed into scenes of beauty and fertility, fitted for being the abodes of renovated moral agents at that period when "the knowledge of the Lord shall cover the earth;" and this extension of population and of cultivation is evidently going forward with rapid progress at the present time in different quarters of the globe. In connexion with this declaration respecting the earth, it is also declared, that the same Almighty Being that arranged the earth for the purpose of replenishing it with inhabitants, likewise "*created the heavens;*" plainly intimating, that as both the fabrics were erected by the same all-wise and omnipotent intelligence, the same wisdom is displayed in both,

* Isaiah xlv. 18

and that the same grand and beneficent designs are accomplished in the globes which roll in the heavens as well as in the constitution of the earth in which we dwell. If the one was created for *use*, for the enjoyment of rational natures, and as a theatre on which the Divine perfection might be displayed, so was the other. It is added, "I am Jehovah, and there is none else;" implying that there is a *unity* of principle, design, and operation, in all his plans and arrangements throughout the universe, however different in the means employed, and however varied the effects produced in different parts of his dominions.

Some, however, may be disposed to insinuate that the Deity may have designs in view, in the creation of matter, of which we are altogether ignorant, and that the planets and other bodies in the heavens may display the Divine glory in some way or another, although they be not peopled with inhabitants. It is readily admitted that we are ignorant of many of the purposes of the Deity, of the details of his operations in the distant regions of creation, and of many of the plans and movements of his moral government; and that, through an eternal lapse of ages, we shall always remain in ignorance of some of the works and ways of the Almighty. But there are certain general principles and views with which the Deity evidently intends that all his rational creatures should be acquainted. It was evidently intended that the visible creation should *adumbrate*, as it were, the character of him who produced it; or that it should serve as a mirror, in which his existence and some of his perfections might be clearly perceived. But if the great globes of the universe were destitute of inhabitants, how could the Divine glory be discovered in their structure? How could a confused mass of rubbish and desolation, however vast and extensive, display the intelligence, the wisdom, and the benevolence of its Maker? It might indicate a power surpassing our comprehension, but it would display no other perfection which tends to excite the admiration, the love, and the adoration of rational beings. Yet we are informed in the scriptures that celestial intelligences celebrate the perfections of Jehovah, "because he hath created all things," and because they perceive "his works" to be "GREAT AND MARVELLOUS." They ascribe to him "wisdom, and glory, and honour, and power, and thanksgiving," from the display of his character which they perceive in his works. But how could they ascribe to him such perfections, if the mightiest of his works were a scene of barrenness and desolation? Wisdom can be attributed only where there appears to be a proportionating of *means* to *ends*; and goodness can have no place where there are no sensitive or rational beings to enjoy the effects of it. It is, therefore, a mere evasion to assert that the Divine glory may be manifested in the celestial globes, although destitute of inhabitants. Every part of the character of God, by which he is rendered amiable and adorable in the eyes of his intelligent offspring, would be obscured and distorted were we for a moment to harbour such a sentiment. For wherein does the Divine glory consist? It chiefly consists in the display of infinite *wisdom*, rectitude, holiness, and unbounded beneficence; and where such attributes are not manifested there cannot be said to be a display of Divine glory. But such attributes could never be traced by man, or by any other order of intelligences, were the planetary bodies and the other orbs of heaven a scene of eternal silence, solitude, and waste; where no percipient being existed to taste the goodness or to adore the perfections of its Creator.

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## SECTION II.

Argument II. *There is a* GENERAL SIMILARITY *among all the bodies of the Planetary System, which tends to prove that they are intended to subserve the same ultimate designs in the arrangements of the Creator.*

In the elucidation of this argument it will be requisite that a variety of facts, some of which have been noticed in the preceding pages, should be brought under review. We are not to imagine that the planets, considered as habitable worlds, are arranged exactly according to the model of our terrestrial habitation; for the Creator has introduced an infinite variety in every department of his works; and we know from observation that there are certain arrangements connected with those bodies which are very different from those which are found in connexion with our globe. But in all worlds destined for the habitation of intellectual nature we should expect to find some general analogy or resemblance in their prominent features, and in those things which appear essential to the enjoyment of such beings. Were we to attend the dissection of any animal—a dog, for example—and perceive the heart, the stomach, the liver, the lungs, the veins, arteries, and other parts essential to life and enjoyment, we could scarcely doubt that the same organs, though perhaps somewhat modified, were likewise to be found in a cat, a bullock, or any other quadruped, and that they served the same purposes in all these animals. In like manner, when we find on our globe certain parts and arrangements essentially requisite to its being a habitable world, and when we likewise

observe similar contrivances connected with other distant globes, we have every reason to conclude that they are intended to subserve similar designs. In accordance with this principle, I shall now proceed to detail a few contrivances and arrangements in the other planets, which evidently indicate that their grand and ultimate design is to afford enjoyment to sensitive and intellectual natures.

1. *All the planets*, both primary and secondary, *are of a spherical or spheroidal figure* similar to that of the earth. I have already shown (p. 132) that this figure is the most capacious and the best adapted to motion, both annual and diurnal, and that the greatest inconveniences would be produced were any world constructed of an angular figure. The only deviation from this figure is to be found in the rings of Saturn. But these rings are not angular bodies; for even the thin exterior edge of the rings is supposed, from some minute observations, to be curved; and, if so, it prevents the inconveniences which would arise from an angular construction. The flat sides of the rings, too, appear to have no angular elevations or protuberances more than what may be supposed from a gently-waving surface such as that of our globe; and although they are not globular bodies, they are *circular*, with thin edges, and are thus calculated for rapid motion along with the planet; and the flat sides, having no angular projections, appear perfectly adapted for being places of habitation, without any of those inconveniences or catastrophes which might ensue had they approximated to a cubical, prismatic, or pentagonal form. The rings, in short, approximate nearer to the globular figure and its conveniences than any other construction could have done, and show us that, although the Creator proceeds in his operations on some grand general principles, yet he is not limited or confined to one particular figure or construction in arranging the celestial worlds. The planets, then, being all of a globular or circular form, appear completely adapted for being the abodes of living beings.

2. The planets are *solid bodies* similar to the earth. They are not merely a congeries of clouds and vapours formed into a globular shape, but possessed of weight, solidity, or gravity. This is evident from the dark and well-defined shadows which they throw on other bodies, and from the attractive influence they exert throughout the system. Their *figure* is a proof that they possess such qualities; for their roundness proceeds from an equal pressure of all their parts tending towards the same centre. Nay, astronomers, by the aid of observation and mathematical calculations, can tell what are the relative gravities or weights of the different planets: what proportion, for instance, the gravitation in Jupiter or Saturn bears to that of our earth, and what influence their attractive power produces on their own satellites, on the motion of comets, and on the smaller and inferior planets. In consequence of this solidity and attractive power, all things connected with their surfaces are preserved in security and prevented from flying off to the distant regions of space; for it is this power, variously modified and directed, that preserves the material universe, and all the orders of beings connected with it, in compact order and harmony, without the influence of which all things in heaven and earth would soon be reduced to a universal chaos. In this respect, then, as well as in the former, the planets are fitted for the support of intellectual beings, furnished with material organs.

3. All the planets have an *annual revolution* round the sun. This revolution, in the case of the earth, combined with the inclination of its axis to the plane of its orbit, produces the variety of seasons; and although we are not to suppose that all the planets have seasons similar to ours, or that the heats of summer and the cold of winter are experienced in other worlds (see pp. 55, 56,) yet there is a certain variety of scene produced by this revolution in all the planets, particularly in those which have their axes of rotation inclined more or less to the plane of their orbits. This variety of scene will be particularly experienced on Saturn and on the surface of its rings; for in the course of one half of the annual revolution the sun will shine on certain parts of these bodies, and during the other half they will be deprived of his direct influence. The annual revolutions of the planets, therefore, appear expedient, in order to produce an agreeable interchange and variety of scene, for the purpose of gratifying their inhabitants. The periods of these revolutions, too, are adjusted with the utmost exactness. The planets perform their circuits without deviating in the least from the paths prescribed, and finish their revolutions exactly in the appointed time, so as not to vary the space of a minute in the course of centuries. Now, were these bodies merely extensive regions of uncultivated desarts, or were they placed in the vault of heaven merely that a few terrestrial astronomers might peep at them occasionally through their glasses, it is not at all likely that so much care and accuracy would have been displayed in marking out their orbits and adjusting their motions and revolutions.

4. The planets perform *a diurnal rotation* round their axes. This has been ascertained in reference to Venus, Mars, Jupiter, and

Saturn, and we may justly conclude, from analogy, that the same is the case in respect to all the other planets. Wherever spots have been discovered on the surface of any planet, it has uniformly been found to have a diurnal rotation. But where no spots or prominences have been observed, it is obvious that no such motion, though it really exist, can be detected. No spots have been observed on the planet Mercury, on account of its smallness and its proximity to the sun; nor on the planet Uranus, on account of its very great distance from the earth; but there can be no doubt whatever that they have a diurnal motion as well as the other planets. By this motion every part of their surface is turned in succession towards the sun, and the alternate changes of day and night are produced. Were no such motion existing, one half of these globes would be entirely uninhabitable, for the enlivening rays of the sun would never cheer its desolate regions, and the other half might be dazzled or parched with heat under the perpetual effulgence of the solar beams. Besides, the continuance of a perpetual day, and the illumination of the sky by an uninterrupted efflux of solar light, would prevent the distant regions of creation from being seen and contemplated, so that no body, except the sun himself, and the planet on which the spectator stood, would be known to exist in the universe. But it appears to have been the intention of the Creator not only to cheer the planets by the invigorating influence of the sun, but likewise to open to the view of their inhabitants a prospect into the regions of distant worlds, that they may behold a display of his wisdom and omnipotence, and of the magnificence of his empire; and this object has been completely effected in every part of the system by impressing upon the planets a motion of rotation, so that there is no body within the range of the solar influence that does not, at one period or another, enjoy this advantage.

The idea of night among the celestial bodies ought not to be associated with gloom, and darkness, and deprivation of comforts. In our world this is frequently the case. A cloudy atmosphere, combined with the fury of raging winds, hurricanes, and the appalling thunderstorm, frequently renders our nights a scene of gloom and terror, especially to the benighted traveller and the mariner in the midst of the ocean. But such gloomy and terrific scenes would never have taken place had our globe and its inhabitants remained in that state of order and perfection in which they were originally created; and, therefore, we are to consider such physical evils as connected with the *moral state* of the present inhabitants of the earth. But even here, amid the gloom and darkness which frequently surround us, *night* not unfrequently opens to view a scene of incomparable splendour and magnificence; a scene which, were it confined to one quarter of the globe, millions of spectators would be eager to travel thousands of miles in order to behold it. In a clear and serene sky, night unfolds to us the firmament bespangled with thousands of stars, twinkling from regions immensely distant, and the planets revolving in their different circuits, all apparently moving around us in silent grandeur. When the moon appears amid the host of stars, the scene is diversified and enlivened. Poets and philosophers in all ages have been charmed and captivated with the mild radiance of a moonlight scene, which partly unveils even the distant landscape, and throws a soft lustre and solemnity both on earth and sky altogether different from their aspect under the meridian sun. But we have already shown (chapter viii.) that the splendour of the heavens during night in some of the other planets is far more magnificent and diversified than what is exhibited in our firmament. The nocturnal scenes in the heavens of Jupiter, Saturn, Uranus, and their rings and satellites, in point of sublimity and variety, exceed every conception we can now form of celestial grandeur and magnificence; and, therefore, it is highly probable, that in those regions the scenes of night will be far more interesting and sublime, and will afford objects of contemplation more attractive and gratifying than all the splendours of their noonday. In this rotation of the planetary orbs there is a striking display both of wisdom and goodness, in causing a means so apparently simple to be productive of so rich a variety of sublime and beneficent effects; and this circumstance of itself affords a strong presumptive evidence that every globe in the universe which has such a rotation is either a world peopled with inhabitants, or connected with a system of habitable worlds; for, without such a motion, the one half at least, of every globe would be unfit for the residence of organized intelligences. It is not improbable that most, if not all the globes of the universe have a diurnal rotation impressed upon them. We find that even the globe of the sun has a motion of this kind, which it performs in the course of twenty-five days; and the phenomena of variable stars have induced some astronomers to conclude that their alternate increase and diminution of lustre is owing to a motion of rotation around their axes.

5. All the planets and their satellites are *opaque bodies*, which derive their lustre from the sun. That Venus and Mercury are opaque globes, which have no light in themselves, is evident from their appearing sometimes with

a gibbous phase, and at other times like a crescent or a half moon; and particularly from their having been seen moving across the disk of the sun like round black spots. Mars being a superior planet, can never appear like a crescent or a half moon; but at the time of its quadrature with the sun it assumes a gibbous phase, somewhat approaching to that of a half moon, which likewise prove that it is an opaque globe. Jupiter and Saturn must always appear round, on account of their great distance from the earth; but that Jupiter is opaque appears from the dark shadows of his satellites moving across his disk when they interpose between him and the sun; and that Saturn is likewise a dark body of itself appears from the shadow of the rings upon its disk. That the moon is an opaque body has been already shown (p. 112,) and it is obvious to almost every observer; and that the satellites of Jupiter and Saturn are opaque appears from their eclipses, and the shadows they project on their respective planets. In this respect both the primary and the secondary planets are bodies analogous to the earth, which is likewise opaque, and derives its light either directly from the sun or by reflection from the moon, except the feeble rays which proceed from the stars. It forms, therefore, a presumptive argument that all these bodies have a similar destination; for we cannot conceive any other globe so well fitted for the habitation of rational beings as that which is illuminated by light proceeding from another body. An inherent splendour on the surface of any globe would dazzle the eyes with its brilliancy, and could never produce such a beautiful diversity of form, shade, and colouring as appears on the landscapes of the earth, by means of the reflections of the solar rays. And, therefore, if the sun be inhabited, it can only be its dark central nucleus, and not the exterior surface of its luminous atmosphere.

6. The bodies belonging to the planetary system *are all connected together by one common principle or law*, namely, the law of gravitation. They are all subject to the attractive influence of the great central luminary; they revolve around it in conformity to the general law, that the squares of their periodical times are proportional to the cubes of their distances; they describe equal areas in equal times; their orbits are elliptical; they are acted upon by centripetal and centrifugal forces; and they all produce an attractive influence on each other, in proportion to their distances and the quantity of matter they contain. Being thus assimilated and combined into one harmonious system, the presumption is, that, however different in point of distance, magnitude, and density, they are all intended to accomplish the same grand and beneficent design, namely, to serve as the abodes of living beings, and to promote the enjoyment of intellectual natures.

Since the planets, then, are all similar to one another in their spherical or spheroidal figures; in their being solid and opaque globes; in their annual and diurnal revolutions; and in being acted upon by the same laws of motion; and since these circumstances are all requisite to the comfort and enjoyment of living beings, it is a natural and reasonable conclusion that their ultimate destination is the same, and that they are all replenished with inhabitants. This earth on which we dwell is one of the bodies possessed of the qualities and arrangements to which we allude; and we know that its chief and ultimate design is to support a multitude of sensitive and intellectual beings, and to afford them both physical and mental enjoyment. Had not this been its principal destination, we are assured, on the authority of Divine revelation, that "*it would have been created in vain.*" We must therefore conclude that all the other globes in our system were destined to a similar end, unless we can suppose it to be consistent with the perfections of Deity that they were created for no purpose.

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## Section III.

Argument III. *In the bodies which constitute the solar system, there are* SPECIAL ARRANGEMENTS *which indicate their* ADAPTATION *to the enjoyments of sensitive and intelligent beings; and which prove that this was the ultimate design of their creation.*

This argument is somewhat similar to the former; but it may be considered separately, in order to prevent an accumulation of too many particulars under one head.

1. The surfaces of the planes *are diversified with hills and valleys, and a variety of mountain scenery.* This is particularly observable in the moon, whose surface is diversified with an immense variety of elevations and depressions, though in a form and arrangement very different from ours (see pp. 113-116.) It cannot be ascertained by direct observation that there are mountains on the surfaces of Jupiter, Saturn, or Uranus, by reason of their great distances from the earth. But that they are rough or uneven globes appears from their reflecting the light to us from every part of their surfaces, and from the spots and differences of shade and colour which are sometimes distinguishable on their disks. For if the surfaces of the planets were perfectly smooth and polished, they could not reflect the light in every direction; the re

flected image of the sun would be too small to strike our eyes, and they would consequently be invisible. (See p. 112.) Indications of mountains, however, have been seen on some of the other planets, particularly on Venus. Spots have been observed on this planet on different occasions, and the boundary between its dark and enlightened hemisphere has appeared jagged or uneven, a clear proof that its surface is diversified with mountains and vales. One of these mountains was calculated by Schroeter to be nearly eleven, and another twenty-two miles in perpendicular elevation; and there can be but little doubt that such inequalities are to be found on the surfaces of all the planets and their satellites, although they are not distinctly visible to us on account of their distance.

The existence of *mountains* on the planets is therefore a proof, or, at least, a strong presumptive evidence, that they are habitable worlds; for a perfectly smooth globe could present no great variety of objects or picturesque scenery, such as we behold in our world, and would doubtless be attended with many inconveniences. The view from any point of such a globe would be dull and monotonous, like the expanse of the ocean, or like the desarts of Zahara or Arabia. It is the beautiful variety of hills and dales, mountains and plains, and their diversity of shadows and aspects, that render the landscapes of the earth interesting and delightful to the painter, the poet, the man of taste, and the traveller. Who would ever desire to visit distant countries, or even distant worlds, if they consisted merely of level plains, without any variety, of several thousands of miles in extent? The mountains add both to the sublimity and the beauty of the surface of our globe; and from the summits of lofty ranges the most enchanting prospects are frequently enjoyed of the rivers and lakes, the hills and vales, which diversify the plains below. But besides the beauty and variety which the diversity of surface produces, mountains are of essential *use* in the economy of our globe. They afford many of the most delightful and salubrious places for the habitations of man; they arrest the progress of stormy winds; they serve for the nourishment of animals, and the production of an infinite variety of herbs and trees; they are the depositories of stones, metals, minerals, and fossils of every description, so necessary for the use of man; and they are the portions of the globe where fountains have their rise, and whence rivers are conveyed to enliven and fertilize the plains. For, if the earth were divested of its mountains, and every part of its surface a dead level, there could be no running streams or conveyance for the waters, and they would either stagnate in large masses or overflow immense tracts of land. Hence it has been arranged by the wisdom of Providence that mountains should exist over all the globe, and that every country should enjoy the numerous benefits which such an arrangement is fitted to produce.

As mountains, then, are part of the arrangements of other globes in the solar system, and as they are essentially requisite in such a world as ours, they may serve similar and even more important purposes in other worlds. In some of the planets they appear to be more elevated and of greater dimensions than on the earth. Although the moon is much less in size than our globe, yet some of its mountains are reckoned to be five miles in perpendicular height. Some of the mountains on Venus are estimated to be four times higher than even this elevation. We may easily conceive what an extensive and magnificent prospect would be presented from the top of such sublime elevations, and what a diversity of objects would be presented to the eye from one point of view. Nor need we imagine there will be any great difficulty in ascending such lofty eminences; for the inhabitants of such worlds may be furnished with bodies different from those of the human race, and endowed with locomotive powers far superior to ours. If, therefore, the planets were found to be perfectly smooth globes, without any elevations or depressions, we should lose one argument in support of their being designed for the abodes of rational beings; but having the characteristic now stated, when taken into consideration with other arguments, it corroborates the idea of their being habitable worlds.

2. The planets, in all probability, are environed with *atmospheres*. It appears pretty certain that the moon is surrounded with such an appendage (see pp. 119–120.) The planet Mars is admitted by all astronomers to be environed with a pretty dense atmosphere, which is the cause of its ruddy appearance (see p. 61, 62;) and indications of an atmosphere have been observed on Venus and some of the other planets. To our world an atmosphere is a most essential appendage. Without its agency our globe would be unfit for being the residence of living beings constituted as they now are; and were it detached from the earth, all the orders of animated nature, and even the vegetable tribes would soon cease to exist. Atmospheres somewhat analogous to ours may likewise be necessary in other worlds. But we have no reason to conclude that they are exactly similar to ours. While our atmosphere consists of a compound of several gaseous substances, theirs may be formed of a pure homogeneous ethereal fluid, possessed of very different properties. While ours is impregnated with dense vapours, and inter-

spersed with numerous strata of thick clouds, the atmosphere of some of the other planets may be free of every heterogeneous substance, and perfectly pure and transparent. Their reflective and refractive powers, and other qualities, may likewise be different from those of the atmosphere which surrounds the earth. Hence the folly of denying the existence of an atmosphere around the moon or any other planet, because a fixed star or any other orb is not rendered dim or distorted when it approaches its margin. For if its atmosphere be either of small dimensions, or perfectly pure and transparent, or of a different refractive power from ours, such a phenomenon cannot be expected. We have no more reason to expect that the atmospheres of other planets should be similar to ours, than that these bodies should be of the same size, have the same diversity of objects on their surface, or be accompanied with the same number of moons.

It is not likely that our atmosphere is precisely in the same state as at the first creation. Its invigorating powers had then an influence sufficient to prolong human existence to a period of a thousand years; but, since the change it underwent at the deluge, the period of human life has dwindled down to little more than "threescore years and ten." The present constitution of our atmosphere, therefore, ought not to be considered as a model by which to judge of the nature and properties of the atmospheres of other worlds. Their atmospheres may be so pure and transparent as to enable their inhabitants to penetrate much further into space than we can do, and to present to them the heavenly bodies with more brilliancy and lustre; and the properties with which they are endowed may be fitted to preserve their corporeal organs in undecaying vigour, and to raise their spirits to the highest pitch of ecstasy, similar to some of the effects produced on our frame by inhaling that gaseous fluid called the *nitrous oxide*. There is only one planet whose atmosphere appears to partake of the impurity and density of that of the earth, and that is the planet Mars; and several other circumstances tend to show that it bears too near a resemblance to our globe. In this respect, then, it gives indication of being a habitable world; but several of the other planets may be abodes of greater happiness and splendour, although no traces of such an appendange can be distinguished by our telescopes. And this very circumstance, that their atmospheres are invisible, should lead us to conclude that they are purer and more transparent than ours, and that the moral and physical condition of their inhabitants is probably superior to what is enjoyed upon earth.

3. There is provision made *for the distribution of light, and heat, and colour* among all the planets and their satellites. On every one of these bodies the sun diffuses a radiance, and, in order that no portion of their surfaces may be deprived of this influence, they appear all to have a motion round their axes. *Light* is an essential requisite to every world, and *colour* is almost equally indispensable. Without colour we should be unable to perceive the forms, proportions, and aspects of the objects which surround us; we could not distinguish one object from another; all the beauties, varieties, and sublimities of nature would be annihilated, and we should remain destitute of the noblest entertainments of vision. It is colour which enlivens every scene of nature, which adds a charm to every landscape, and gives an air of beauty and magnificence to the spacious vault of heaven. Now colour exists in the solar rays, without which, or some similar radiance, every object is either invisible or wears a uniform aspect. On whatever objects these rays fall, colour is produced; they have the same properties in every part of the system as on our globe, and, therefore, must produce colours of various hues on the objects connected with the remotest planets, according to the nature of the substances on which they fall. Light and colour, then, being essential to every globe intended for the habitation of living beings, abundant provision has been made for diffusing their benign influence through every part of the planetary system. Heat is likewise an agent which appears necessary to every world; and it is, doubtless, distributed in due proportions throughout the system, according to the nature of the substances of which the planets are composed, and the constitution of their inhabitants. But light, and colour, and heat are agencies which can only have an ultimate respect to sensitive and intellectual beings; and, therefore, where no such beings exist or are intended to exist, no such provision would be made by a wise and intelligent agent. Such care as appears to have been taken for the communication of the agencies of light, heat, and colour, would never have been exercised for the sake of rocks and desarts, and scenes of sterility and desolation. The existence of *light*, with all the enchanting effects it produces, necessarily supposes the existence of *eyes*, in order to enjoy its beneficial influence; and, therefore, organized beings, endowed with *visual organs*, must exist in all those regions where contrivances have been adapted for its regular and universal diffusion; otherwise the universe might have remained a scene of eternal darkness.

4. The principal primary planets *are provided with secondary planets or moons*, to afford them light in the absence of the sun,

as well as to accomplish other important purposes. The three largest planets of the system are accommodated with no fewer than *seventeen* of those nocturnal luminaries, and probably with several more which lie beyond the reach of our telescopes. Our earth has one; and it is not improbable that both Mars and Venus are attended by at least one satellite. These attendants appear to increase in number in proportion to the distance of the primary planet from the sun. Jupiter has four such attendants; Saturn seven; six have been discovered around Uranus; but the great difficulty of perceiving them, at the immense distance at which we are placed, leads to the almost certain conclusion that several more exist which have not yet been detected. While these satellites revolve round their respective planets, and diffuse a mild radiance on their surfaces in the absence of the sun, they also serve the same purposes to one another; and their primaries, at the same time, serve the purpose of large resplendent moons to every one of their satellites, besides presenting a diversified and magnificent scene in their nocturnal sky. No satellite has yet been discovered attending the planet Mercury, nor is it probable that any such body exists. But we have already shown (pp. 146–148) that Venus and the earth serve the purposes of satellites to this planet, Venus sometimes appearing six times as large, and the earth two or three times as large as Venus does to us at the period of its greatest brilliancy; so that the nights of Mercury are cheered with a considerable degree of illumination. Here, then, we perceive an *evident design* in such arrangements, which can have no other ultimate object in view than the comfort and gratification of intelligent beings. For a retinue of moons, revolving around their primary planets at regular distances and in fixed periods of time, would serve no useful purpose in throwing a faint light on immense desarts, where no sensitive beings, furnished with visual organs, were placed to enjoy its benefits; nor, if this were the case, is it supposable that so much skill and accuracy would have been displayed in arranging their distances and their periodical revolutions, which is accomplished with all the accuracy and precision which are displayed in the other departments of the system of nature.

The *small density* of the larger and more remote planets, and *the diminution of the weight of bodies on their surfaces* on this account, and by their *rapid rotation* on their axes, appear to be instances of design which have a respect to sentient beings. The density of Jupiter is little more than that of water, and that of Saturn about the density of cork. Were these planets as dense as the planet Mercury, or had they even the density of the earth, organized beings like man would be unable to traverse their surfaces. If the density of Jupiter, for example, were as great as that of the earth, the weight of bodies on its surface would be eleven times greater than with us; so that a man weighing 160 pounds on the earth would be pressed down on the surface of Jupiter with a force equal to one thousand seven hundred and sixty pounds. But the gravity of bodies on the surface of this planet is only about twice as great as on the surface of the earth; and *this gravitating power is diminished by its rapid rotation on its axis.* For the centrifugal force which diminishes the weight of bodies is *sixty-six* times greater on Jupiter than on the earth, and will relieve the inhabitants of one eighth part of their weight, which they would otherwise feel if there were no rotation; so that a body weighing 128 pounds if the planet stood still, would weigh only 112 pounds at its present rate of rotation, which will afford a sensible relief and diminution of weight (see p. 75, Art. *Jupiter.*) The same may be said, with some slight modifications, in relation to Saturn. There must, therefore, have been a *design*, or a wise and prospective contrivance in such arrangements, to suit the exigencies and to promote the comfort of organized intelligences; otherwise, had Jupiter and Saturn been as much denser than the earth as they are lighter, every body would have been riveted to their surfaces with a force which beings like man could never have overcome; and moving beings with such organical parts as those of men would have had to drag along with them a weight of eight or ten thousand pounds.

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In the preceding statements I have endeavoured to show that there is a *general similarity* among all the bodies of the planetary system, and that there are *special arrangements* which indicate their *adaption* to the enjoyment of sensitive and intellectual beings. Let us now consider more particularly the force of the argument derived from such considerations:

That the Divine Being has an *end* in view in all his arrangements, and that this end is in complete correspondence with his infinite wisdom and goodness, and the other perfections of his nature, is a position which every rational Theist will readily admit. That some of the prominent designs or general ends which the Deity intended to accomplish may be traced in various departments of his works, is likewise a position which few or none will deny. That design may be inferred from its effects, is a principle which mankind generally recognize in their investigations of the operations

both of nature and of art. That man would justly be accused of insanity who, after inspecting the machinery of a well-constructed clock, and perceiving that it answered the purpose of pointing out the divisions of time by hours, minutes, and seconds with the utmost accuracy, should *deny* that its various parts were formed and arranged for the very purpose which the machine so exactly fulfils; at least, that the pointing out of the hours and minutes was one of the main and leading objects which the artist had in view in its construction. It is a law of our nature which we cannot resist, that from the effect the design may be inferred; and that, wherever art or contrivance appears exactly adapted to accomplish a certain end, that end was intended to be accomplished. We cannot doubt for a moment of the final causes of a variety of objects and contrivances which present themselves to view in the world we inhabit. We cannot err in concluding, for example, that the ears, legs, and wings of animals were made for the purpose of hearing, walking, and flying. On the same principle we are led to conclude, that as animals are formed with mouths, teeth, and stomachs to masticate and digest their food, so vegetables and other organized bodies were formed for the purpose of affording that nourishment which the animal requires. No one will take upon him to deny that the eye was intended for the purpose of vision. The coats and humours of which it is composed, and the muscles which move it in every direction, in their size, shape, connexion, and positions, are so admirably adapted to this end, and the transparency of the *cornea*, and the *humours*, the opacity of the *uvea*, and the semi-opacity and concavity of the *retina*, are so necessary to transmit and refract the rays of light in order to distinct vision, that it appears as evident it was designed for this purpose, as that telescopes were constructed to discover the colours, shapes, and motions of distant objects. And as the eye was constructed of a number of nice and delicate parts for the purpose of vision, so light was formed for the purpose of acting upon it and producing the intended effect, without the agency of which vision could not be produced. The one is exactly adapted to the other; for no other substance but light can affect the eye so as to produce vision, and no other organ of sensation is susceptible of the impressions of light, so as to convey a perception of any visible object. In all such cases, the adaption of one contrivance to another, and the intention of the Contriver, are quite apparent.

It is true, indeed, that we cannot pretend to explore *all the ends or designs* which God may have had in view in the formation of any one object or department of the universe. For an eternal and omniscient Being, whose wisdom is unsearchable, and whose eye penetrates through all the regions of immensity, may have subordinate designs to accomplish, which surpass the limited faculties of man, or even of angels, to comprehend. But to investigate and to perceive *some* of the main and leading ends which were designed in the arrangement of certain parts of the universe, is so far from being presumptuous and unattainable, that it would be blindness and folly in a rational creature not to discover them; particularly in such instances as those to which we have now alluded. For it appears to be the intention of the Deity, in displaying his works to intelligent minds, that these works shall exhibit a manifestation of his attributes, and particularly of his wisdom, goodness, and intelligence; and he has endowed them with faculties adequate to enable them to perceive some traces of his footsteps and of the plan of his operations. But while he permits us to perceive some of the grand lineaments of his designs, there may be numberless minute and subordinate ends which lie beyond the sphere of our investigations. Were a peasant brought into the observatory of an astronomer, and shown an instrument calculated to point out the sun's place in the ecliptic, its declination and right ascension, the day of the month, &c., and particularly the *hour* of the day, it would be presumptuous in such a person to pretend to ascertain *all* the intentions of the artist, or all the uses for which such a machine was constructed; but when he beheld the ordinary marks of a sundial, and the shadow of the gnomon accurately pointing to the hour, he could not fail at once to perceive that this was *one* principal end which the contriver had in view. In like manner, while we evidently perceive that one principal design of the creation of the sun was to enlighten the earth and other bodies which move around it, it also serves several subordinate purposes. It directs the course of winds, promotes evaporation and the growth of vegetables; it retains the planets in their orbits; it kindles combustible substances by means of convex glasses and concave mirrors; it enables us to measure time by means of dials; it directs the geographer to determine the elevation of the pole and the latitude of places; it guides the navigator in his course through the ocean, and even its eclipses serve many useful purposes, both in chronology and astronomy; and it may serve similar or very different purposes, with which we are unacquainted, among the inhabitants of other worlds. All these purposes, and many more of which we are ignorant, may have entered into the designs of the almighty Creator, although, in the first instance, we might have been unable to discover or appreciate

them. As "the works of the Lord are great," so they must "be sought out," or diligently investigated, in order that we may clearly perceive the manifold designs of infinite wisdom.

Let us now apply these principles to the subject more immediately before us. We have seen that, in the distant bodies of our system, there are special contrivances and arrangements, all calculated to promote the enjoyment of myriads of intelligent agents. We have presented before us a most august and astonishing assemblage of *means*; and if the Contriver of the universe is possessed of wisdom, there must be an *end* proportionate to the utility and grandeur of the means provided. Arrangements nearly similar, but much inferior in point of extent and magnificence, have been made in relation to the globe on which we live. We know the final cause, or, at least, one of the principal designs for which it was created, namely, to support sensitive and intellectual beings, and to contribute to their enjoyment. If, then, the Creator acts on the same principle—in other words, if he displays the same intelligence—in other regions of the universe as he does in our world, we must admit that the planetary globes are furnished with rational inhabitants. There is one essential attribute which enters into all our conceptions of the Divine Being, namely, *that he is possessed of infinite wisdom*. This perfection of his nature is displayed in all the general arrangements he has made in this lower world, where we find one part nicely adapted to another, and every thing so balanced and arranged as to promote the comfort of sentient beings. In consequence of his being possessed of this perfection, he must be considered, in *all* his operations throughout the immensity of space, as proportionating the means to the end, and selecting the best means possible for the accomplishment of any design; for in such contrivances and operations true wisdom consists.

But now let us suppose for a moment that the vast regions on the surfaces of the planets are only immense and frightful desarts, devoid of inhabitants; *wherein does the wisdom of the Creator appear on this supposition?* For what purpose serves the grand apparatus of rings and moons for adorning their sky and reflecting light on their hemispheres? Why are they made to perform annual and diurnal revolutions, and not fixed in the same points of infinite space? Why are the larger and remoter planets furnished with more moons than those which are nearer the source of light? Why are their firmaments diversified with so many splendid and magnificent objects? Why is their surface arranged into mountains and vales? Why has so much contrivance been displayed in devising means for the illumination of every portion of their surfaces, and diffusing over them a variety of colours? The answers to such questions would, then, be, to illuminate an immense number of dreary wastes, and to produce days and nights, and a variety of seasons, for the sole benefit of interminable desarts, or, at most, of mountains of marble or rocks of diamonds; to afford them light enough to see to keep their orbits, lest they might miss their way in the pathless spaces through which they move! Is such an apparatus requisite for such a purpose? *Would this be an end worthy of* INFINITE WISDOM? Would it at all correspond with the dignity and grandeur of the means employed? Would it comport with the boundless intelligence of Him "who formed the earth by his wisdom, and stretched out the heavens by his *understanding?*" To maintain such a position would be to *distort* the Divine character, and to undermine all the conceptions we ought to form of the Deity, as wise, amiable, and adorable, and as "great in counsel and mighty in operation." If we beheld an artist exerting his whole energies, and spending his whole life in constructing a large complex machine which produced merely a successive revolution of wheels and pinions, without any useful end whatever in view, however much we might extol the ingenuity displayed in some parts of the machine, we could not help viewing him as a fool or a maniac in bestowing so much labour and expense to no purpose. For it is the *end* or design intended which leads us to infer the wisdom of the artist in the means employed. And shall we consider the ALL-WISE AND ADORABLE CREATOR OF THE UNIVERSE as acting in a similar manner? The thought would be impious, blasphemous, and absurd It is only when we recognize the Almighty as displaying infinite wisdom in all his arrangements throughout creation, and boundless beneficence in diffusing happiness among countless ranks of intelligent existence, that we perceive him to be worthy of our admiration and gratitude, and of our highest praises and adorations. We are, therefore, irresistibly led to the conclusion, that the planets are the abodes of intelligent beings, since every requisite arrangement has been made for their enjoyment. This is a conclusion which is not merely probable, but absolutely certain; for the opposite opinion would rob the Deity of the most distinguishing attribute of his nature, by virtually denying him the perfection of infinite wisdom and intelligence.

## SECTION IV.

Argument IV. The scenery of the heavens, as viewed from the surfaces of the

larger planets and their satellites, forms a presumptive proof that both the planets and their moons are inhabited by *intellectual* beings.

In the preceding chapter I have described at some length the celestial phenomena of the planets, both primary and secondary. From these descriptions it appears that the most glorious and magnificent scenes are displayed in the firmament of the remoter planets, and particularly in those of their satellites. Even the firmament of the moon is more striking and sublime than ours. But in the firmaments of some of the satellites of Jupiter and Saturn there are celestial scenes peculiarly grand and splendid, surpassing every thing which the imagination can well represent, and these scenes diversified almost every hour. What should we think of a globe appearing in our nocturnal sky 1300 times larger than the apparent size of the moon, and every hour assuming a different aspect? of five or six bodies twenty or thirty times larger than our moon appears, all in rapid motion, and continually changing their phases and their apparent magnitudes? What should we think of a globe filling the twentieth part of the sky, and surrounded with immense rings, in rapid motion, diffusing a radiance over the whole heavens? When Jupiter rises to his satellites, and especially when Saturn and his rings rise to his nearest moons, a whole quarter of the heavens will appear in one blaze of light. At other times, when the sun is eclipsed, or when the dark sides of these globes are turned to the spectator, the *starry* firmament will open a new scene of wonders, and planets and comets be occasionally beheld in their courses through the distant regions of space.

The sublime and magnificent scenes displayed in those regions; the diversified objects presented to view; the incessant changes in their phases and aspects; the rapidity of their apparent motions; and the difficulty of determining the *real* motions and relative positions of the bodies in the firmament, and the true system of the world, lead us to the conclusion that the globes to which we allude are replenished, not merely with sensitive, but with *intellectual* beings. For such sublime and interesting scenes cannot affect inanimate matter, nor even mere sentient beings such as exist in our world; and we cannot suppose that the Creator would form such magnificent arrangements to be beheld and studied by *no rational beings* capable of appreciating their grandeur and feeling delight in their contemplation. If creation was intended as a display of the perfections and grandeur of the Divine Being, there must exist intelligent minds to whom such a display is exhibited; otherwise the material universe cannot answer this end, and might, so far as such a design is concerned, have remained for ever shut up in the recesses of the Eternal Mind. Such scenes could not have been intended merely for the instruction or gratification of the inhabitants of the earth. For no one of its population has yet beheld them from that point of view in which their grandeur is displayed, and not one out of a hundred thousand yet knows that such objects exist. We are, therefore, irresistibly led to the conclusion that intelligent minds exist in the regions of Jupiter, Saturn, and Uranus, for whose pleasure and gratification these sublime scenes were created and arranged. Those minds, too, in all probability, are endowed with faculties superior in intellectual energy and acumen to those of the inhabitants of our globe. For the rapidity and complexity of the motions presented in the firmament of some of the satellites of Jupiter and Saturn, the variety of objects exhibited to view, and the frequent and rapid changes of their phases and apparent magnitudes, are such as to require the exertion of intellectual faculties more powerful and energetic than ours in order to determine the real motions and positions of the globes around them, and to ascertain the order of the planetary system of which they form a part. And it is likewise probable that their organs of vision are more acute and penetrating than those of men; otherwise they will never be able to discover either the earth, Mars, Mercury, or Venus, and, consequently, may suppose that such bodies have no existence.

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## Section V.

Argument V. The doctrine of a plurality of worlds may be argued from the consideration that, in the world we inhabit, *every part of nature is destined to the support of animated beings.*

There is, doubtless, a certain degree of pleasure in contemplating the material world, and surveying the various forms into which matter has been wrought and arranged, particularly in the admirable structure and movements of systems of bodies such as those which compose the planetary system. But there is something still more interesting and wonderful presented to the mind when we contemplate the worlds of life. The material world is only, as it were, the shell of the universe; the mere *substratum* of thought and sensation; living beings are its inhabitants, for whose sake alone matter is valuable, and for whose enjoyment it appears to have been created. In the organization of animated

existences, in the various parts of which they are composed, in the adaptation of one part or organ to another, in their different functions, and the multifarious movements of which they are susceptible, without taking into consideration the soul that animates them, there is a display of the most admirable mechanism and the nicest contrivance, which is not to be found in earth or stones, in rocks of diamonds, or even in the figure of a planet and its motion round the sun.

Hence we find that the world in which we live teems with animated existence. Man is the principal inhabitant, for whose use and accommodation, chiefly, the terraqueous globe was formed and arranged. Had not the Creator intended to place upon its surface beings endowed with rational faculties, capable of enjoying happiness and recognizing the perfections of its author, it is not probable that it would have been created. "God made man in his own image," and "gave him dominion over the fish of the sea, over the fowls of the air, and over every living thing that moveth upon the earth." After the light was formed, the bed of the ocean prepared, and the waters separated from the dry land; after luminaries were placed in the firmament, and plants and animals of all kinds brought into existence, the world appeared so magnificently adorned that it might have been thought perfect and complete. But all nature was yet destitute of sentiment and gratitude; there were no beings capable of recognizing the Power that formed them, or of praising the Author of their varied enjoyments. The world was still in a state of imperfection, till an intelligence was formed capable of appreciating the perfections of the Creator, of contemplating his works, and of offering to him a tribute of grateful adoration. Therefore "God created man in his own image," as the masterpiece of creation, the visible representative of his Maker, and the subordinate ruler of this lower world.

But although this globe was created chiefly for the residence of man, it was not destined *solely* for his enjoyment. It is impossible for him to occupy the *whole* of its surface, or of the appendages with which it is connected. There are extensive marshes, impenetrable forests, deep caverns, and the more elevated parts of lofty mountains, where human feet have never trod. There is a vast body of water which covers more than two thirds of the surface of the globe, and the greater part of the atmosphere which surrounds the earth, which men cannot occupy as permanent abodes. Yet these regions of our world are not left destitute of inhabitants. Numerous tribes of animals range through the uncultivated deserts, and find ample accommodation suited to their nature, in rocks and mountains, in dens and caves of the earth. The regions of the air are filled with winged creatures of every kind, from the ostrich and the eagle to the numerous tribes of flying insects almost invisible to the unassisted eye. The ocean teems with myriads of inhabitants which no man can number, of every form and size, from the mighty whale to the numerous tribes of *Medusæ*, of which several thousands of *billions* are contained in a cubical mile of water. Every sea, lake, and river is peopled with inhabitants; every mountain and marsh, every wilderness and wood, is plentifully stocked with birds, and beasts, and numerous species of insects, all of which find ample accommodation, and every thing necessary for their comfort and subsistence. In short, every part of matter appears to be peopled: almost every green leaf and every particle of dust has its peculiar inhabitants. Not only are the larger parts of nature occupied with living beings, but even the most minute portions of matter teem with animated existence. Every plant and shrub, and almost every drop of water, contains its respective inhabitants. Their number, in some instances, is so great, and their minuteness so astonishing, that thousands of them are connected within a space not larger than a grain of sand. In some small pools covered with a greenish scum, of only a few yards in extent, there are more living creatures than there are human beings on the surface of the whole earth.

Multitudes of animated beings are found in situations and circumstances where we should never have expected to perceive the principle of life. The juices of animals and plants, corrupted matter, excrements, smoke, dry wood, the bark and roots of trees, the bodies of other animals, and even their entrails, the dunghill, and the dirty puddle, the itch, and other disorders which are attended with blotches and pimples, and even the hardest stones and rocks, serve to lodge, and in some measure to feed, numerous tribes of living beings. The *number* of such creatures exceeds all human calculation and conception. There may be reckoned far more than a hundred thousand species of animated beings, many of these species containing individuals to the amount of several hundreds of times the number of the human inhabitants of our globe. It is supposed by some that the tremulous motion observed in the air during summer may be produced by millions of insects swarming in the atmosphere; and it has been found that the light which is seen on the surface of the ocean during the nights of summer is owing to an innumerable multitude of small luminous worms or insects sporting in the waters. All the numberless species of

animals which exist on the different departments of our globe are likewise infinitely diversified in their forms, organs, senses, members, faculties, movements, and gradations of excellence. As Mr. Addison has observed, "the whole chasm of nature, from a plant to a man, is filled up with divers kinds of creatures rising one above another by such a gentle and easy ascent, that the little transitions and deviations from one species to another are almost insensible. This intermediate space is so well husbanded and managed, that there is scarce a degree of perception which does not appear in some one part of the world of life." Here we have an evidence both of the infinite wisdom and intelligence of the Divine Being, and of his boundless goodness in conferring existence and happiness on such a countless multitude of percipient beings.

Since, then, it appears that every portion of matter in our world was intended for the support and accommodation of animated beings, it would be absurd in the highest degree, and inconsistent with the character of the Deity and his general plan of operation, to suppose that the vast regions of the planets, so exceedingly more expansive than our globe, are left destitute of inhabitants. Shall one small planet be thus crowded with a population of percipient beings of all descriptions, and shall regions four hundred times more expansive be left without one living inhabitant? Can the Deity delight to communicate enjoyment in so many thousands of varied forms to unnumbered myriads of sensitive existences in our terrestrial sphere, and leave the noblest planets of the system without a single trace of his benevolence? Can we suppose, for a moment, that while his *wisdom* shines so conspicuous in the mechanism of the various tribes of animals around us, no similar marks of intelligence are to be found in other regions of the universe? Such conclusions can never be admitted, unless we suppose that infinite wisdom and goodness have been *exhausted* in the arrangements which have been made in relation to our world, or that the Great Source of felicity is indifferent about the communication of happiness.

As far as our observation extends, it appears that the material world is useless, except in the relation it bears to animated and intellectual beings. *Matter* was evidently framed for the purpose of *mind;* and if we could suppose that the vast masses of matter in the heavens had no relation to mind, they must, then, have been created in vain; a supposition which would derogate from the moral character and the perfections of Him who is "the only wise God." A superior nature cannot be supposed to be formed for the sake of an inferior. A skilful artist would never think of designing that which is of the greatest dignity, or which requires the utmost precision and the nicest mechanism, for the sake of the inferior part of his workmanship. He does not construct the wheels and pinions of an orrery for the sake of the handle by which they are moved, or of the pedestal on which the instrument stands; nor does he contrive a timepiece merely for the sake of the shell or case in which it is to be inclosed. In like manner, we cannot imagine that *man* was made for the sake of the brutes, or the inferior animals for the sake of vegetables, or the yearly production of vegetables for the relief and comfort of the soil on which they grow. This would be to invert the order of the universe, and to involve us in the most palpable absurdity. The order of things always *rises upward*, by gentle and regular degrees, from inanimate matter, through all the gradations of vegetable, animal, and immaterial existence, till we arrive at the Eternal and Incomprehensible Divinity. Hence it appears that the earth must have been formed, not for itself, but for the sake of the vegetable, sensitive, and intellectual beings it supports; and, by a parity of reasoning, the planets, most of which are much more spacious and more magnificently adorned, must have been formed and arranged for the sake of superior natures.

"Existence," as a certain writer has observed, "is a blessing to those beings only which are endued with perception, and is, in a manner, thrown away upon dead matter any further than as it is subservient to beings which are conscious of their existence." Accordingly we find, from the bodies which lie under our observation, that matter is only made as the basis and support of living beings, and that there is little more of the one than what is necessary for the existence and the ample accommodation of the other. The earth, as to amplitude of space, would contain a hundred times the number of animated beings it actually supports; and the ocean might perhaps contain thousands more than what are found amid its recesses; but, in such a case, they would not have free scope for their movements, nor experience all the comforts and accommodations they now enjoy.

From what has been stated, it appears that the Divine Goodness is of so communicative a nature that it seems to *delight* in conferring existence and happiness on every order of perceptive beings, and, therefore, has left no part connected with the world in which we live without its inhabitants; and that no creature capable of feeling the pleasure of existence might be omitted in the plan of benevolence, there is an almost infinite *diversity* in the

rank and order of percipient existence. The scale of sensitive being begins with those creatures which are raised just above dead matter. Commencing at the polypus and certain species of shellfish, it ascends by numerous gradations till it arrives at man. How far it may ascend beyond this point is beyond the limits of our knowledge to determine. Had only one species of animals been created, none of the rest would have enjoyed the pleasures of existence. But in the existing state of things, all nature is full of enjoyment, and that enjoyment endlessly diversified, according to the rank and the percipient powers of the different species of animated existence. It would, therefore, be a reflection on the *goodness* as well as on the wisdom of the Divine Being, were we to suppose that no traces of Divine beneficence were to be found amid the expansive regions of the planetary globes. It would form a perfect *contrast* to the operations of Infinite Benevolence, as displayed in our terrestrial system, and would almost lead us to conclude that the same Almighty Agent did not preside in both these departments of the universe. But we may rest assured that the Deity always acts in harmony with his character throughout every part of his dominions; and, therefore, we may confidently conclude that countless multitudes of sensitive and intellectual beings, far more numerous and diversified than on earth, people the planetary regions.

From what has been stated on this subject, we may likewise conclude with certainty that the planetary worlds are not peopled merely with animal existences, but also *with rational and intellectual natures*. For the scenes displayed in most of the planets cannot be appreciated by mere sensitive beings, nor are they calculated to afford them any gratification. Besides, if it be one great design of the Creator to manifest the glory of his perfections to other beings, none but those who are furnished with rational faculties are capable of recognizing his attributes as displayed in his works, and of offering to him a tribute of thanksgiving and adoration. Such intelligences, we have every reason to believe, may far surpass the human race in their intellectual powers and capacities. There is an infinite gap between man and the Deity, and we have no reason to believe that it is entirely unoccupied. There is a regular gradation from inanimate matter and vegetative life through all the varieties of animal existence till we arrive at man. But we have no reason to believe that the ascending scale terminates at the point of the human faculties, unless we suppose that the soul of man is the most perfect intelligence next to the Divinity. If the scale of being rises by such a regular process to man, by a parity of reasoning we may suppose that it still proceeds gradually through those beings that are endowed with superior faculties; since there is an immensely greater space between man and the Deity than between man and the lowest order of sensitive existence. And although we were to conceive the scale of *intellectual* existence above man rising thousands of times higher than that which intervenes between inanimate matter and the human soul, still there would be an infinite distance between the highest created intelligence and the Eternal Mind which could never be overpassed. It is quite accordant with all that we know of the perfections and operations of the Deity to conclude that such a progression of intellectual beings exists throughout the universe; and, therefore, we have reason to believe that in some of the planets of our system there are intellectual natures far superior, in point of mental vigour and capacity, to the brightest geniuses that have ever appeared upon earth; and in other systems of creation the scale of spiritual progression may be indefinitely extended far beyond the limits to which human imagination can penetrate. In the contemplation of such scenes of percipient and intelligent existence. we perceive no boundaries to the prospect; the mind is overwhelmed amid the immensity of being, and feels itself unable to grasp the plans of Eternal Wisdom, and the innumerable gradations of intelligence over which the moral government of the Deity extends; and, therefore, we may justly conclude wonders of power, wisdom, and benevolence still remain for the admiration of intellectual beings, which the scenes of eternity alone can disclose.

Intellectual beings may likewise be distinguished into those which are linked to *mortal*, and those which are connected with *immortal* bodies. In the present state of our terrestrial system immortal bodies cannot exist. Had immortality been intended for man on earth, Infinite Wisdom would have adopted another plan; for the constitution of the earth, the atmosphere, and the waters, is not adapted to the support and preservation of immortal beings; that is, of those intelligences which inhabit a system of corporeal organization. From the reciprocal action of solids and fluids, of earth, air, and water, *life* results; and this very action continued, according to the laws which now operate, is the natural cause of *death*, or the dissolution of the corporeal system. But in other worlds a system of means may be adapted for preserving in perpetual activity, and to an indefinite duration, the functions of the corporeal machine which is animated by the intellectual principle; as would probably have happened in the case of

man, had he retained his original moral purity and his allegiance to his Maker. Intelligent beings may likewise exist which are destined to pass from one state of corporeal organization to another, in a long series of changes, advancing from one degree of corporeal perfection to another, till their organical vehicles become as pure and refined as light, and susceptible of the same degree of rapid motion. The butterfly is first an egg, then a worm, afterward it becomes a chrysalis, and it is not before it has burst its confinement, that it wings its flight, in gaudy colours, through the air. Man is destined to burst his mortal coil, to enter a new vehicle, and at last to receive a body "incorruptible, powerful, glorious, and immortal." Varieties analogous to these may exist throughout other regions of the universe. If there are not in nature two leaves precisely alike, or two trees, two cabbages, two caterpillars, or two men and women exactly similar in every point of view in which they may be contemplated, how can we suppose that there can be two planets or two systems of planets exactly alike, or that the corporeal organs and faculties of their inhabitants in every respect resemble each other? Every globe and every system of worlds has doubtless its peculiar economy, laws, productions, and inhabitants. This conclusion is warranted from all that we know of the operations of the Creator; it exhibits, in a striking point of view, the depths of his wisdom and intelligence, and it opens to immortal beings a prospect boundless as immensity, in the contemplation of which their faculties may be for ever exercised, and their views of the wonders of Creating Power and wisdom continually extending, while myriads of ages roll away.

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In the preceding pages I have endeavoured to illustrate the doctrine of a plurality of worlds, from the considerations that there are bodies in the planetary system of such *magnitudes* as to afford ample scope for myriads of inhabitants; that there is a *general similarity* among all the bodies of the system, which affords a presumptive evidence that they are intended to subserve the same ultimate designs; that, connected with the planets, there are *special arrangements* which indicate their *adaptation* to the enjoyment of sensitive and intellectual beings; that the *scenery of the heavens, as viewed from the surfaces of the larger planets and their satellites*, forms a presumptive proof of the same position; and that the fact that *every part of nature in our world is destined to the support of animated beings*, affords a powerful argument in support of this doctrine. These arguments, when viewed in all their bearings, and in connexion with the wisdom and benevolence of the Divine Being, may be considered as amounting to moral demonstrations that the planets and their satellites, as well as other departments of the universe, are the abodes of sensitive and intelligent natures. These, however, are not all the considerations or arguments which might be brought forward in proof of this position. Many others, founded on a consideration of the nature and relations of things, and the attributes of the Divinity, and particularly some powerful arguments derived from the records of Revelation, might have been stated and particularly illustrated. But I shall leave the further consideration of this topic to another volume, in which we shall take a survey of the scenery of the starry firmament, and of other objects connected with the science of the heavens.

On the whole, the doctrine of a plurality of worlds is a subject of considerable importance, and in which every rational being, who is convinced of his immortal destination, is deeply interested. It opens to our view a boundless prospect of knowledge and felicity beyond the limits of the present world, and displays the ineffable grandeur of the Divinity, the magnificence of his empire, and the harmonious operation of his infinite perfections. Without taking this doctrine into account, we can form no *consistent* views of the character of Omnipotence and of the arrangements which exist in the universe. Both his wisdom and his goodness might be called in question, and an idea of the Supreme Ruler presented altogether different from what is exhibited by the inspired writers in the records of Revelation. When, therefore, we lift our eyes to the heavens, and contemplate the mighty globes which roll around us; when we consider that their motions are governed by the same common laws, and that they are so constructed as to furnish accommodation for myriads of perceptive existence, we ought always to view them as the abodes of intelligence and the theatres of Divine Wisdom on which the Creator displays his boundless beneficence; for "his tender mercies," or the emanations of his goodness, "are diffused *over all his works*." Such views alone can solve a thousand doubts which may arise in our minds, and free us from a thousand absurdities which we must otherwise entertain respecting the Great Sovereign of the universe. Without adopting such views, the science of the heavens becomes a comparatively barren and uninteresting study, and the splendour of the nocturnal sky conveys no ideas of true sublimity and grandeur, nor is it calculated to inspire the soul with sentiments of love and adoration. In short, there appears to be no

medium between remaining in ignorance of all the wonders of Power and Wisdom which appear in the heavens, and acquiescing in the general views we have attempted to illustrate respecting the economy of the planets, and their destination as the abodes of reason and intelligence. But, when such views are recognized, the bodies in the heavens become the noblest objects of human contemplation, the Deity appears invested with a character truly amiable and sublime, and a prospect is opened to immortal beings of a perpetual increase of knowledge and felicity, throughout all the revolutions of an interminable existence.

# APPENDIX.

## PHENOMENA OF THE PLANETS FOR THE YEARS 1838, 1839.

For the sake of those readers who may feel a desire occasionally to contemplate the heavens and to trace the motions of the planetary orbs, the following sketches are given of the positions and motions of the planets for two years posterior to 1837.

### POSITIONS, ETC., OF THE PLANETS FOR 1838.

#### 1. *The Planet Mercury.*

This planet can be seen distinctly by the naked eye only about the time of its greatest elongation; and to those who reside in northern latitudes it will scarcely be visible, even at such periods, if it be near the utmost point of its southern declination.

The following are the periods of its greatest elongation for 1838: January the 3d it is at its *eastern* elongation, when it is 19¼ degrees *east* from the sun, and will be seen in the *evening* about thirty or forty minutes after sunset, near the south-west, at a little distance from the point where the sun went down. But as it is then in 20° 41′ of south declination, its position is not the most favourable for observation. Its next greatest elongation is on February 12, when it is 26° 10′ to the *west* of the sun, and will be seen in the *morning*, before sunrise, near the south-eastern quarter of the horizon. April 25 it will again be seen in the *evening* at its eastern elongation, 20° 20′ east of the sun, when it is in 21° 43′ of north declination. It will be seen at this time about 15 degrees north of the western point of the horizon, almost immediately above the place where the sun went down. During five days before and after the time now specified there will be favourable opportunities for detecting Mercury with the naked eye or with a small opera-glass. On June 12 is its greatest *western* elongation, at which time it is 23° 5′ west of the sun, and is to be looked for in the *morning*, before sunrise, near the north-eastern part of the horizon; but the strong twilight at this season will probably prevent it from being distinguished by the naked eye. Its next greatest *eastern* elongation is on August 23, when it is 27¼ degrees from the sun. It will be seen, for nearly an hour after sunset, a little to the south of the *western* point of the compass, and a few degrees above the horizon. It may be seen during ten or twelve days before the period here stated, and six or eight days after it. This will form one of the most favourable periods which occur throughout this year for observing Mercury. October 4 it will again be at its greatest *western* elongation, when it will be seen in the *morning* in a direction nearly due east. December 17 it is at its greatest *eastern* elongation, but its southern declination being then more than 24 degrees, it will set in the S. W. by S. point of the compass a few minutes after the sun, and will consequently be invisible to the naked eye.

The periods most favourable for detecting this planet in the *evenings* are April 25 and August 23; and in the *mornings*, February 12 and October 4. During the interval of a week or ten days, both before and after the time of the greatest elongation, the planet may generally be seen in a clear sky, when in such favourable positions as those now stated.

#### 2. *The Planet Venus.*

This planet will appear as an evening star during the months of January and February. About the beginning of January it will be seen near the south-west quarter of the heavens a few minutes after sunset. About the beginning of February it will set nearly due west. It will be visible in the evening till

about the 25th of February, after which its nearness to the sun will prevent it from being distinguished. Throughout the whole of its course during these two months it will appear of the figure of a crescent when viewed with a telescope, and the crescent will appear most slender about the end of February (see Fig. 12, p. 38.) On March 5 it passes its *inferior* conjunction with the sun, after which it will be no longer seen in the evenings for the space of ten months. It then becomes a morning star; and, about eight days after its conjunction, will be seen in the *morning*, before sunrise, a little to the south of the eastern point of the horizon. From this period till near the middle of May it will appear of a crescent form. Its greatest brilliancy will be on April 10; its greatest elongation from the sun on May 14, when it will appear of nearly the form of a half moon, and its *superior* conjunction on December 18, soon after which it will again be seen as an evening star.

The brilliancy of this planet is such that it can scarcely be mistaken by any observer, especially when its position in the heavens is pointed out.

### 3. *The Planet Mars.*

This planet will not be much noticed by common observers till near the end of the year. About the beginning of March it is in conjunction with the sun, when it is furthest from the earth, about a month or two before and after which period it is scarcely distinguishable from a small star. From April to December it will be visible only in the *morning*, in an easterly direction; but its apparent size will gradually increase till the end of the year. It is distinguished from the fixed stars and from the other planets by its ruddy appearance.

### 4. *The Planets Vesta, Juno, Ceres, and Pallas.*

These planets are not perceptible by the naked eye. The best time for observing them with telescopes is when they are at or near the period of their opposition to the sun, when they are nearest the earth, and even then it will be difficult to detect them without the assistance of transit or equatorial instruments.

*Vesta* will be in opposition to the sun on the 29th December, its right ascension being $6^h\ 31'\ 47''$, and its declination $22°\ 4\frac{1}{2}'$ north. At midnight it will be due south, at an elevation of 60 degrees above the horizon, in the latitude of 52 degrees north, about 15 degrees to the south-west of the star Pollux, and $7\frac{1}{2}$ degrees north of *Gamma* Gemini.

*Juno* is in opposition on the 17th June, in right ascension $17^h\ 46\frac{1}{2}'$, and south declination $4\frac{1}{2}°$. It will be on the meridian at midnight, at an elevation of $33\frac{1}{2}$ degrees above the southern horizon.

Neither *Ceres* nor *Pallas* will be in opposition to the sun during this year.

### 5. *The Planet Jupiter.*

This planet will make a very conspicuous appearance in the heavens during the winter and spring mouths. About the beginning of January it will rise, a little to the north of the eastern point of the horizon, a few minutes after ten o'clock in the evening, and will pass the meridian, at an elevation of $43\frac{1}{2}$ degrees, about half past four in the morning. About the middle of February it will rise about seven in the evening, nearly in the same direction, and will come to the meridian about half past one in the morning. During the months of January and February it will be seen either in the evenings or the mornings. About the middle of January it will be seen, in a south-westerly direction, about six o'clock in the morning. From the beginning of March till the end of August it will be seen in the evenings without interruption when the sky is clear. On the 22d September it is in conjunction with the sun, but it will seldom be noticed for a month before this period. During the months of November and December it will be again seen in the east, only in the morning, some time before the rising of the sun.

This planet can scarcely be mistaken, as it is next to Venus in apparent magnitude and splendour. It will appear most brilliant about the beginning of March, when it is in opposition to the sun, and its satellites and belts will present an interesting sight when viewed with a good telescope. At present (November 22, 1837,) four belts, nearly equidistant from each other, are distinctly visible with a power of 200 times. Their appearance is very nearly similar to what is represented in Fig. 56, p. 81, so that a considerable change has taken place in their appearance since last June, when they appeared nearly as in Fig. 52, p. 77. At that time the middle belt was the only one easily perceptible, while the other two, at the north and south extremities, appeared extremely faint and obscure. At present all the four belts are distinctly marked.

### 6. *The Planet Saturn.*

This planet passed its conjunction with the sun on the 12th November, 1837. From the beginning of the year till about the middle of April it will be visible chiefly in the mornings. On the first of January it will rise near the south-east, about twenty minutes past four in

the morning, and will pass the meridian about forty-eight minutes past eight, at an elevation of 21 degrees above the southern horizon. On the first of April it will rise at half past ten in the evening, and about midnight will be seen near the south-east about 10 or 12 degrees above the horizon. From this period Saturn will be visible in the evenings till near the end of October, rising every evening at an earlier hour than on the preceding. On the 16th May it is in opposition to the sun, when it will rise near the south-east at half past seven, and come to the meridian at midnight. During the months of August, September, and October, it will be seen chiefly in the *south-west* quarter of the heavens after sunset, at a small elevation above the horizon. It will be very perceptible during September and October, on account of its low altitude at sunset. It will be in conjunction with the sun on the 24th November.

This planet is not distinguished for its brilliancy to the naked eye, though it exhibits a beautiful appearance through the telescope. It is of a dull leaden colour, and is not easily distinguished from a fixed star except by the steadiness of its light, never presenting a twinkling appearance as the stars do, and from which circumstance it may be distinguished from neighbouring stars. The best times for telescopic observations on this planet will be in the months of April and May, when its ring will appear nearly as represented in Fig. 63, p. 91.

### 7. *The Planet Uranus.*

This planet is, for the most part, invisible to the naked eye. The best time for detecting it, by means of a telescope, is when it is at or near the period of its opposition to the sun, which happens on the 3d September. At that time it passes the meridian at midnight, at an elevation of about 30½ degrees above the horizon. It is situated nearly in a straight line between the star *Fomalhaut* on the south and *Markab* on the north, being nearly in the middle of the line, about 22½ degrees distant from each. It is in the neighbourhood of several small telescopic stars. On account of its slow motion, its position in respect to the above stars will not be much altered for a month or two. On the 1st November it passes the meridian at eight o'clock in the evening. Its *right ascension*, or distance from the first point of Aries, is then $22^h$ 42′, and its declination 9° 4′ south.

N. B.—In the above statements the observer is supposed to be in fifty-two degrees north latitude. In places a few degrees to the north or south of this latitude, a certain allowance must be made for the times of rising, and the altitudes which are here specified. To those who reside in lower latitudes than fifty-two degrees, the altitudes of the different bodies will be *higher*, and to those in higher latitudes the altitudes above the horizon will be *lower* than what is here stated.

## PHENOMENA OF THE PLANETS FOR 1839.

### 1. *Mercury.*

The greatest *western elongation* of this planet happens on the 26th of January, when it is 24° 50′ west of the sun. It will be seen near the south-east a little before seven in the morning. On the seventh of April, and a few days before and after it, it will be seen in the *evening* in a direction west by north. On the 24th of May it will be seen in the morning, in a direction a little to the north of the eastern point, before sunrise. Its next elongation will happen on the fifth of August, when it is twenty-seven and one-third degrees distant from the sun. At this period, and a fortnight before and a little after, it will be seen near the west point, or a little north of it, about nine o'clock in the evening or a few minutes before it. This will be a favourable opportunity for distinguishing this planet with the naked eye. It will be again seen in the morning, about five o'clock, a little to the north of the east point, on September 18. Its next greatest elongation will be on the 30th of November, when it will appear in a direction south-west by south about the time of sunset. This will be a very unfavourable position for attempting to distinguish Mercury. It passes its inferior conjunction with the sun on the 18th December.

### 2. *Venus.*

This planet will be an evening star from the beginning of the year till 6th October, when it passes its inferior conjunction with the sun. It will not, however, be much noticed till about the beginning of March, on account of its nearness to the sun and its southern declination. It will appear most brilliant during the months of May, June, July, August, and beginning of September, when it will be seen at a considerable elevation in the western and north-western quarter of the heavens a few minutes after sunset. About the middle of October, or a few days before, it will appear as a *morning* star near the *south-eastern* quarter of the sky, and will continue as a morning star till near the end of the year

### 3. *Mars.*

During the months of February, March, and April, this planet will appear in its greatest lustre. It will be in opposition to the sun on the 12th March, at which period it is nearest to the earth, and will appear twenty-five times larger in surface than in the opposite part of its orbit. At this period it will rise about half past five in the evening, a little to the north of the *east* point, and will come to the meridian at midnight, at an altitude of forty-five degrees. It will be easily distinguished from the neighbouring stars by its size and its ruddy appearance. At this time the planet Jupiter will appear in a direction about twenty-two degrees south-east of Mars. From the month of May till the end of the year Mars will be visible in the evenings, but its apparent size will be gradually diminishing, and, on account of its southern declination, will not be much noticed after the month of September. On the 19th July, at forty-six minutes past nine o'clock in the evening, Mars and Jupiter will be in conjunction, at which time Mars will be one degree and a half to the south of Jupiter. They will then be seen near the western point, at a small elevation above the horizon.

### 4. *Vesta, Juno, Ceres, and Pallas.*

*Juno* arrives at its opposition to the sun on the 12th October, at $1^h\ 32'$ P.M. It passes the meridian at midnight, or at $12^h\ 2\frac{1}{2}'$, at an altitude of $34°\ 21'$, and is then about twelve degrees west of the star *Mira*. Declination $3°\ 39'$ south, and right ascension, $1^h\ 26'$.

*Pallas* is in opposition to the sun April 1, at $7^h\ 10'$ A.M. Right ascension $13^h\ 12'\ 42''$. Declination $14°\ 21'$ *north*. It passes the meridian at midnight, at an elevation of $52°\ 22'$. It will then be about fourteen degrees south-west from the bright star *Arcturus*.

*Ceres* is in opposition April 6, at $7^h\ 8'$ P.M. Right ascension $13^h\ 23'\ 40''$. Declination $7°\ 54'$ *north*. It passes the meridian at midnight, at an altitude of nearly forty-six degrees. It will then be seen, by means of a telescope, at about twelve degrees south-west from *Arcturus*.

The planet Vesta is not in opposition to the sun, this year.

### 5. *Jupiter.*

During the months of January and February this planet will be chiefly seen in the morning. On the 12th January it rises about midnight, a little to the south of the eastern point of the horizon, and comes to the meridian at forty minutes past five in the morning, at an altitude of about thirty-two degrees. On the 12th March it rises at eight in the evening, and will be seen near the south-east part of the heavens about eleven and twelve o'clock, P.M. On the 3d April, it is in opposition to the sun, when it rises about half past six, P.M., and comes to the meridian about midnight. From this period it will form a conspicuous object in the evening sky till near the end of September. It arrives at its conjunction with the sun on the 22d October, after which it will be seen only in the morning throughout the month of December and the latter part of November. On the 20th March, at one o'clock in the morning, all the satellites of Jupiter will appear on the east, or right hand side of the planet, *in the order of their distances* from Jupiter. The same phenomenon will happen on August 1, at forty-five minutes past eight, and 20th September, at $7^h$ P.M.

### 6. *Saturn.*

This planet will be visible only in the morning during the months of January, February, and March, and will then be seen towards the southern and south-eastern parts of the sky. On the first of February it will rise, about half past two in the morning, near the south-east, and will come to the meridian at forty-nine minutes past seven, at an elevation of eighteen degrees above the horizon. On the first of April it will rise at forty-two minutes past eleven in the evening, and will pass the meridian a few minutes before four in the morning. It will be in opposition to the sun on the 29th May, when it will rise in the south-east at forty-five minutes past seven P.M., and will pass the meridian at midnight, at an altitude of eighteen and a half degrees above the southern point of the horizon. This will be a favourable opportunity for viewing its ring with good telescopes, when it will appear nearly in its full extent, as represented Fig. 65, p. 91. From this period Saturn will generally be visible in the evening till about the end of October, when its low altitude and its proximity to the sun, will prevent its being distinguished by the naked eye. About the middle of August, at nine o'clock in the evening, it will be seen near the south-west at a small elevation above the horizon. It will be in conjunction with the sun on the fifth December, after which it will be invisible to the naked eye till the beginning of 1840.

### 7. *Uranus.*

This planet will be in opposition to the sun on the 7th of September, at 30 minutes past seven in the evening. Right ascension $23^h\ 4'$, or $346°$ east from the point of Aries, reckoned on the equator. South declination $6°\ 52\frac{1}{2}'$. It will come to the meridian at

midnight at an elevation of 31° 8′ above the horizon. At this time it is in the immediate vicinity of the star *Phi*, Aquarii. On the 25th of August, at 20 minutes past one in the morning, it is in conjunction with this star, being only 15′, or one quarter of a degree to the north of it, at which time the planet and the star, if viewed with a telescope of moderate power, will both appear in the field of view. The months of August, September, October, and November will be the most eligible periods for detecting this planet with the telescope. On the 1st of November it passes the meridian at 15 minutes past eight in the evening, at an altitude of 30½ degrees.

N.B.—The preceding descriptions of planetary phenomena are chiefly intended to inform common observers as to the seasons of the year when the different planets may be seen, and the quarters of the heavens to which they are to direct their attention in order to distinguish them.

It may not be improper to observe, that the planets in general cannot be distinguished by the naked eye for about a month before and after their conjunctions with the sun, except *Venus*, which may frequently be seen within a week before and after its *inferior* conjunction. But this planet will sometimes be invisible to the naked eye for a month or two after its *superior* conjunction with the sun.

Should the above descriptions of celestial phenomena prove acceptable to general readers, they may be continued in future years.

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THE

# SIDEREAL HEAVENS

AND

OTHER SUBJECTS CONNECTED WITH

# ASTRONOMY,

AS ILLUSTRATIVE OF THE CHARACTER OF THE DEITY, AND OF AN INFINITY OF WORLDS.

"The worlds were framed by the word of God."—PAUL.

BY THOMAS DICK, LL. D.,

AUTHOR OF "CELESTIAL SCENERY,"—"THE CHRISTIAN PHILOSOPHER," etc., etc

HARTFORD:
PUBLISHED BY A. C. GOODMAN & CO.

1850.

# PREFACE.

The favourable reception which the volume entitled "CELESTIAL SCENERY" has met with from the public, both in Britain and America, has induced the Author to extend his survey to other sublime scenes connected with the science of Astronomy The chief object of the work alluded to was to illustrate, more fully than had previously been attempted, the scenes connected with the planetary system. In the present volume, the Author has directed the attention of his readers to scenery of a still more elevated and sublime description, connected with the "Sidereal Heavens." All the facts related to this subject, which can be considered as interesting to general readers, have been particularly detailed, and in such a manner as to be generally comprehensible by those who have little knowledge of mathematical science, or the more abstruse parts of astronomy.

In describing such sublime scenes as are here unfolded, the Author, as on former occasions, has freely indulged in such remarks and moral reflections as were naturally suggested by the grandeur of his subject; and has endeavoured to lead the minds of his readers to the contemplation of the attributes and the agency of that Almighty Being, by whom the vast system of universal nature was at first brought into existence, and by whose superintending care it is incessantly conducted in all its movements.

The subject of a plurality of worlds has been resumed, and additional arguments, both from reason and revelation, have been brought forward so as to exhibit this position, not merely as conjectural or highly probable, but as susceptible of moral demonstration. For the gratification of amateur observers possessed of telescopes, particular descriptions have been given of the *positions* or some of the more remarkable phenomena in the sidereal heavens, that they may be induced to contemplate them with their own eyes. For a similar reason the Author has described the various aspects of the heavens throughout the year, and the position of the planets for 1840 and 1841. As the subject of *comets* was unavoidably omitted in the preceding volume, the author has condensed, in the concluding chapter, the greater part of the facts which have been ascertained respecting the nature, phenomena, and influence of those anomalous bodies.

It was originally intended, had the limits of the present volume permitted, to direct the attention of the student to other subjects related to the scenery of the heavens, and to the construction and application of some of those instruments which are devoted to celestial observations. Should the work now published meet with a favourable reception, the Author intends—in a smaller volume than the present—to elucidate some of the subjects to which he alludes, especially the following:—the construction and use of optical instruments, particularly the reflecting and achromatic telescope, and the equatorial. As the Author has performed a great variety

of experiments in relation to such instruments, he hopes to have it in his power to suggest some new and useful hints in reference to their construction and improvement. The doctrine of eclipses and occultations, the precession of the equinoxes, &c.—the construction of observatories, and the manner of using astronomical instruments,—the *desiderata* in astronomy, and the means by which the progress of the science may be promoted,—the practical utility, physical and moral, of astronomical studies,—their connexion with religion, and the views they unfold of the attributes and the empire of the Creator, with several other correlative topics, will likewise be the subject of consideration. The whole to be illustrated with appropriate engravings, many of which will be original.

BROUGHTY FERRY, near DUNDEE,
*January* 24, 1840.

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# THE

# SIDEREAL HEAVENS.

## INTRODUCTION.

In a work lately published under the title of "Celestial Scenery," I endeavoured to exhibit a pretty full display of all the prominent facts connected with the motions, distances, magnitudes, and other phenomena of the planets, both primary and secondary, and of the observations and reasonings by which they are supported. These bodies forming a part of the solar system to which we belong, and lying within the limits of measurable distance, can be more distinctly surveyed, and their magnitudes and other phenomena more accurately investigated, than those of the remoter orbs of the firmament. Hence, in consequence of the accurate observations of modern times, we can now speak with a degree of certainty and precision respecting their order and arrangement, their periodical revolutions, their distances from the sphere we occupy and from the centre of the system, their real bulk, the appearance of their surfaces, and the objects which diversify their respective firmaments. But when we pass the boundary of the planetary system, and attempt to explore the orbs which lie beyond it, we have to travel, as it were, through dark and pathless regions, we have to traverse an immense interval which has hitherto baffled all the efforts of human science and ingenuity to determine its extent. The fixed stars lie completely beyond the dominions of the sun; they feel not his attractive influence, they revolve not around him as a centre, nor are they enlightened by his effulgence. It follows that our knowledge of those remote luminaries must be extremely imperfect, and our views of the distant regions in which they are placed comparatively limited and obscure.

But notwithstanding the immeasurable distance of the starry regions, and the limited nature of human vision, we are not altogether ignorant of those remote and unexplored dominions of Omnipotence, or of the magnitude and splendour of the bodies they contain. The telescope has enabled us to penetrate the vast spaces of the universe, and has opened a *vista* through which thousands of suns and systems are distinctly beheld, which would otherwise have been for ever veiled from the view of mortals. It has extended the boundaries of our vision thousands of times beyond its natural limits, and collected the scattered rays of light from numerous distant orbs, which, without its assistance, would never have entered our eyes. It has served the purpose of a celestial vehicle to carry us towards the heavens, and has produced the same effect on our visual powers as if we had been actually transported thousands of millions of miles nearer the unexplored territories of creation. Guided by this noble instrument, scenes and objects have been disclosed to view of which former generations could form no conception, and which lead the reflecting mind to the most elevated views of the perfections of the Deity, and to the most expansive prospects of the grandeur and magnificence of his empire.

For a considerable period after the true system of the world was recognized, astronomers were disposed to consider the stars as so many insulated luminaries, scattered almost at random throughout the vast spaces of the universe. Having engaged in no very *extensive* surveys of the celestial vault, and resting contented with the idea that the stars were so many suns, dispersed in a kind of magnificent confusion through the immensity of space, they seemed to have formed no conception of any specific difference in the nature of these bodies, or of any systematic arrangement as existing among them. Hence it happened that no discoveries of importance were made in the region of the stars, from the time of Huygens and Cassini till near the latter part of the eighteenth century; so that a whole century elapsed without mate-

rially enlarging our views of the sidereal heavens, and of the variety, order, and arrangement of the numerous bodies which every portion of those expansive regions presents to view. During the last sixty or seventy years, the attention of astronomers has been more particularly directed to sidereal observations; and among those who have laboured with success in this department of astronomical investigation, the late Sir William Herschel stands pre-eminent. Fired with a noble zeal for the improvement of his favourite science, and for the enlargement of his views of the distant regions of creation, he set to work with enthusiastic ardour, and constructed with his own hands telescopes of a size and magnifying power far superior to what had ever before been attempted. Mounted on the top of his forty-feet reflecting telescope, he not only discovered new bodies within the limits of the planetary system, but brought to light innumerable phenomena in regions of the firmament where the eye of man had never before dared to penetrate. He explored the Milky-way throughout all its profundities, and found that whitish zone of the heavens to consist of a multitude of stars "which no man could number," fifty thousand of them having sometimes passed through the field of his telescope in the space of an hour. During the coldness and profound silence of many sleepless nights, he surveyed almost every portion of the celestial concave, and discovered more than two thousand *nebulæ*, or starry systems, of various forms and descriptions, along with multitudes of double, triple, and quadruple stars which had formerly been unknown, and ascertained, from the change of their relative positions, some of their real motions and periods of revolution. After more than half a century spent in unwearied observations of the heavens, this illustrious astronomer departed from this earthly scene, in 1822, without infirmities and without pain, in the eighty-fourth year of his age, leaving a son to prosecute his labours endued with virtues and talents worthy of his father, and whose observations and researches have already enriched the science of astronomy, and extended our views of the sidereal system.

This department of astronomical science may be considered as still in its infancy. Years, and even centuries, must roll on, and the number of astronomical observers must be increased a hundredfold, before the sidereal investigations now going forward can be nearly completed. A more extensive knowledge of the history of the heavens, of the bodies which lie hid in the yet unexplored regions of space, and of the changes and diversified motions to which they are subject, is doubtless reserved for generations to come; and from the attention which has lately been paid to this subject, and the ardour with which it is now prosecuted in different parts of the world, we have reason to expect that new scenes of divine wisdom and omnipotence will be gradually unfolding, and new and interesting results deduced from the nocturnal labours of those who have devoted themselves to celestial investigations. To what extent our knowledge of the objects of this science may yet reach, it is impossible for us to anticipate. The objects in the heavens present a scene which is absolutely boundless,—which all the generations of men that may arise till the termination of our terrestrial system will never be able fully to explore; a scene which will doubtless engage the study and contemplation of numerous orders of intellectual beings throughout all the revolutions of eternity.

In the following work, I propose to give only a very condensed view of the leading objects which have been lately discovered in the sidereal heavens. The facts in relation to this subject will be selected chiefly from the observations of Sir W. Herschel, and several other astronomers, and some of them from personal observation. Most of the facts to which I allude were ascertained by Sir W. Herschel by means of telescopes of great size and power, and a considerable number of the double and triple stars, stellar and planetary nebulæ, and other phenomena, cannot be perceived with instruments of an ordinary size. Certain interesting facts, too, particularly with regard to the motions of double stars, have lately been brought to light by the observations of Sir John Herschel, made in the southern hemisphere; but the bodies to which I allude cannot be seen in the northern latitudes in which we reside. A considerable portion therefore of our information on this subject must necessarily depend on the observations of the astronomers to whom I allude, and the statements they have published to the world; but these observations have, for the most part, been abundantly verified by other observers.

It shall be our endeavour to state the prominent facts connected with the sidereal heavens in as plain and perspicuous a manner as possible; and while it forms no part of our plan to frame hypotheses, or launch out into theoretical disquisitions, we shall offer those remarks, and freely indulge in those moral reflections, which the contemplation of such august objects are calculated to suggest. The scenes we intend to exhibit are not only the workmanship of God, but display the glory of his attributes and the magnificence of his empire in a degree, and upon a scale, far surpassing what can be seen in any other department of creation: and therefore, in all

our surveys of those grand and multifarious objects, we ought invariably to connect our views and investigations with the supreme agency of Him who brought them into existence, and to cherish those sentiments and emotions which may inspire us with reverence and adoration of that glorious and incomprehensible Being "by whom the worlds were framed," "who created all things, and for whose pleasure they are and were created."

## CHAPTER I.

*A General View of the Starry Heavens, with representations of detatched portions of the Firmament.*

If we could suppose a community of rational beings to have lived for ages in some subterraneous grottoes far beneath the surface of the earth, and never to have visited the exterior portions of our globe, their ideas must have been extremely circumscribed, and their enjoyments extremely imperfect, even although they had been furnished with every thing requisite for their animal subsistence. Could we imagine that such beings were all at once transported to the surface of the earth, with what astonishment and wonder would they be seized when they beheld the expansive landscape of the world, the lofty mountains towering to the clouds,—the hills crowned with magnificent forests,—the plains stretching to the boundaries of the horizon, and adorned with colours of every shade,—the expansive lake, like a magnificent mirror, embosomed among the hills,—the rivers rolling their watery treasures towards the ocean,—and the sun in the firmament revolving around the circuit of the sky, diffusing his light and heat on every surrounding object! Above all, with what emotions of admiration would they be filled when they beheld the solar globe descending below the western horizon, and soon after the moon displaying her silver crescent in the sky, and the stars, one after another, emerging from the blue ethereal, till the whole celestial concave appeared all over spangled with a thousand shining orbs, emitting their radiance from every part of the cope of heaven, and all moving, with an apparently slow and silent motion, along the spaces of the firmament! Such expansive and novel scenes would undoubtedly overwhelm the faculties of such beings with astonishment, and transport, and wonder inexpressible.

We are placed, perhaps, in a situation nearly similar in regard to the remote regions of the universe, as the beings we have supposed were situated with respect to the ample prospects we enjoy on the surface of our globe. Were such beings, from their subterranean abodes, to look through a narrow funnel which presented them with a feeble glimpse of our upper world, and of a portion of the sky, the view thus obtained would somewhat resemble the partial glimpse we have yet acquired of the splendour and sublimities of the distant universe; and were we transported to those far distant scenes, which appear through our telescopes only like dim specks of light, we should, doubtless, be as much overpowered with astonishment and wonder at the magnificent scenes which would open to our view, as our supposed subterraneous inhabitants could be at the amplitude and grandeur of our terrestrial abode.

In our present habitation we are confined to a mere point in the infinity of space. Ample as our prospects are, it is not improbable that the views we have already attained bear a less proportion to the whole immensity of creation than the limited range of a microscopic animalcule bears to the wide expanse of the ocean. What is seen by human eyes, even when assisted by the most powerful instruments, may be as nothing when compared to what is unseen and placed for ever beyond the view of mortals. Since the heavens first began to be contemplated, our views have been carried thousands of times further into the regions of space than the unassisted eye could enable us to penetrate; and at every stage of improvement in optical instruments our prospects have been still further extended, new objects and new regions of creation have appeared rising to view, in boundless perspective, in every direction, without the least indication of a *boundary* to the operations of Omnipotence; leaving us no room to doubt that all we have hitherto discovered is but a small and inconsiderable part of the length and breadth, and the height and depth of *immensity*. We may suppose, without the least degree of improbability or extravagance, that, were the whole of the *visible* system of creation annihilated, though it would leave a void immeasurable and incomprehensible by mortals, it would appear to the eye of Omniscience only as an inconsiderable blank scarcely discernible amidst the wonders of wisdom and omnipotence with which it is surrounded.

Such views and deductions have been de-

rived from attentive surveys of the STARRY HEAVENS. These heavens present, even to the untutored observer, a sublime and elevating spectacle. He beholds an immense concave hemisphere, surrounding the earth in every region, and resting, as it were, upon the circle of the horizon. Wherever he roams abroad, on the surface of the land or of the ocean, this celestial vault still appears encompassing the world; and after travelling thousands of miles, it seems to make no nearer an approach than when the journey commenced. From every quarter of this mighty arch numerous lights are displayed, moving onward in solemn silence, and calculated to inspire admiration and awe. Even the rudest savages have been struck with admiration at the view of the nocturnal heavens, and have regarded the celestial luminaries either as the residences of their gods, or the arbiters of their future destinies.

But to minds enlightened with the discoveries of science and revelation the firmament presents a scene incomparably more magnificent and august. Its concave rises towards immensity, and stretches, on every hand, to regions immeasurable by any finite intelligence; it opens to the view a glimpse of orbs of inconceivable magnitude and grandeur, and arranged in multitudes which no man can number, which have diffused their radiance on the earth during hundreds of generations; it opens a vista which carries our views into the regions of *infinity*, and exhibits a sensible display of the *immensity* of space, and of the boundless operations of Omnipotence; it demonstrates the existence of an eternal and incomprehensible Divinity, who presides in all the grandeur of his attributes over an unlimited empire; it overwhelms the contemplative mind with a display of the riches of his wisdom and the glories of his OMNIPOTENCE; it directs our prospects to the regions of other worlds, where ten thousand times ten thousands of intelligences, of various orders, experience the effects of divine love and beneficence. Amidst the silence and the solitude of the midnight scene, it inspires the soul with a solemn awe and with reverential emotions; it excites admiration, astonishment, and wonder in every reflecting mind, and has a tendency to enkindle the fire of devotion, and to raise the affections to that ineffable Being who presides in high authority over all its movements. While contemplating, with the eye of intelligence, this immeasurable expanse, it teaches us the littleness of man, and of all that earthly pomp and splendour of which he is so proud; it shows us that this world, with all its furniture and decorations, is but an almost invisible speck on the great map of the universe; and that our thoughts and affections ought to soar above all its sinful pursuits and its transitory enjoyments. In short, in this universal temple, hung with innumerable lights, we behold, with the eye of imagination, unnumbered legions of bright intelligences, unseen by mortal eyes, celebrating in ecstatic strains, the perfections of Him who is the creator and governor of all worlds,—we are carried forward to an eternity to come, amidst whose scenes and revolutions alone the magnificent objects it contains can be contemplated in all their extent and grandeur.

It is an evidence of the depraved and grovelling dispositions of man that the firmament is so seldom contemplated with the eye of reason and devotion. No other studies can present an assemblage of objects so wonderful and sublime; and yet, of all the departments of knowledge which are generally prosecuted, no one is so little understood or appreciated by the bulk of mankind as the science of the heavens. Were it more generally studied, or its objects were frequently contemplated, it would have a tendency to purify and elevate the soul, to expand and ennoble the intellectual faculty, and to supply interesting topics for conversation and reflection. The objects in the heavens are so grand, so numerous, so diversified, and so magnificent, both in their size and in the rapidity of their motions, that there appears no end to speculation, to inquiry, to conjecture, to incessant admiration. There is ample room for all the faculties of the brightest genius to be employed, and to expatiate in all their energy on this boundless theme; and were they thus employed more frequently than they are, our views of the arrangement, and the nature of the magnificent globes of heaven, might be rendered still more definite and expansive.

While contemplating the expanse of the starry heavens, the mind is naturally led into a boundless train of speculations and inquiries. Where do these mighty heavens begin, and where do they end? Can imagination fathom their depth, or human calculations and figures express their extent? Have angels or archangels ever winged their flight across the boundaries of the firmament? Can the highest created beings measure the dimensions of those heavens, or explore them throughout all their departments? Is there a boundary to creation beyond which the energies of Omnipotence are unknown, or does it extend throughout the infinity of space? Is the immense fabric of the universe yet completed, or is almighty power still operating throughout the boundless dimensions of space, and new creations still starting into existence? At what period in duration did this mighty fabric commence, and when will it be completed? Will a period ever arrive when

the operations of creating power shall cease, or will they be continued throughout all the revolutions of eternity? What various orders of intellectual beings people the vast regions of the universe? With what mental energies and corporeal powers are they endowed? Are they confined to one region of space, or are they invested with powers of locomotion, which enable them to wing their flight from world to world? Are they making rapid advances, from age to age, in intellectual improvement? Has moral evil ever made inroads into those remote regions of creation, or are all their inhabitants confirmed in a state of innocence and bliss? Is their history diversified by new and wonderful events, and do changes and revolutions happen among them? Are all the tribes of intellectual natures throughout creation connected together by certain relations and bonds of union, and will a period ever arrive in the future revolutions of eternity when they shall have had an intimate correspondence with one another? These, and hundreds of similar inquiries, are naturally suggested by serious contemplations of the objects connected with the starry heavens, and they have a tendency to lead the mind to sublime and interesting trains of thought and reflection, and to afford scope for the noblest energies of the human soul.

But leaving such reflections, in the mean time, let us now take a general view of the starry heavens as they appear to the eye of a common spectator.

When an untutored observer attempts to take a serious survey of the starry firmament for the first time, he is apt to be bewildered at the idea of the immense multitude of stars which seem to present themselves in every part of the sky, and the apparent confusion with which they seem to be arranged. He is apt to think that they are absolutely innumerable, and that all attempts to enumerate or to classify them would be in vain. There is something so magnificent and overpowering in a cursory view of a clear starry sky, that the mind shrinks from the idea of ever being able to form a distinct conception of the number and order of those luminous orbs, or of their distances and magnitudes; but the genius and industry of man have, in numerous instances, accomplished what at first view appeared beyond the reach of the human faculties. All the stars *visible to the naked eye* have been numbered, and their relative positions determined, with as much precision as the longitudes, latitudes, and bearings of places on the surface of the globe; and there is not a star visible to the unassisted eye, but its precise position can be pointed out, not only during the shades of night, but even during the day, when the sun is shining in all its splendour.

In order to prevent confusion in our first surveys of the starry heavens, let us fix upon a certain portion of the firmament, and the more conspicious stars which lie in its immediate vicinity. Let us suppose ourselves contemplating the heavens about the middle of January, at eight o'clock in the evening, in the latitude 52° north. At that time, if we turn our faces toward the south, we shall behold the splendid constellation of *Orion* a little to the east of the meridian, or nearly approaching the south. This constellation forms one of the most striking and beautiful clusters of stars in the heavens, and is generally recognized even by common observers. It is distinguished by four brilliant stars in the form of an oblong, or parallelogram; and particularly by three bright stars in a straight line near the middle of the square, or parallelogram, which are known by the names of "the Three Kings," or the "Ell," or "Yard." They are also termed Orion's *belt*; and in the book of Job, "the *bands* of Orion;" and the space they occupy is exactly three degrees in length. The line passing through these three stars points to the *Pleiades*, or seven stars, on the one side, and to *Sirius*, or the Dog Star, on the other. The equinoctial circle passes through the uppermost of these stars, which is called *Mintika*. They are situated about eight degrees west from the *solstitial colure*, or that great circle which passes through the poles of the heavens, and the first points of Cancer and Capricorn, in which the sun is in his greatest declination north and south, which happens on the 21st of June and 21st of December. There is a row of small stars which run down obliquely below the belt, and seem to hang from it, which is denominated the *sword* of Orion. About the middle of this row of stars there is perceived, by means of the telescope, one of the most remarkable *nebulæ* in the heavens. The whole number of stars visible by the naked eye in this constellation has been reckoned at about 78; of which two are of the first magnitude—namely, *Rigel*, in the left foot on the west, and *Betelguese*, on the east shoulder. They are connected by a line drawn through the uppermost star of the belt. There are four stars of the second magnitude, three of the third, and fifteen of the fourth; but several thousands of stars have been perceived by good telescopes within the limits of this constellation.

North by west of Orion is the constellation *Taurus*, or the Bull, one of the signs of the zodiac. The *Pleiades*, or the seven stars, so frequently alluded to both in ancient and mordern times, form a portion of this constella-

tion. At the time now supposed, they are a very little beyond the meridian to the west, and about thirty-seven degrees north by west of the belt of Orion, at an elevation above the horizon of about sixty-four degrees. This cluster was described by the ancients as consisting of seven stars, but at present only six can be distinguished by the naked eye. With powerful telescopes, however, more than 200 stars have been counted within the limits of this group. The *Hyades* is another cluster, situated about eleven degrees south-east from the Pleiades, consisting chiefly of small stars, so arranged as to form a figure somewhat like the letter V. On the left, at the top of the letter, is a star of the first magnitude, named *Aldebaran*, or the Bull's Eye, which is distinguished from most of the other stars by its *ruddy* appearance. This constellation is situated between *Perseus* and *Auriga* on the north, and has *Gemini* on the east, *Aries* on the west, and *Orion* and *Eridanus* on the south. It consists of about 140 stars visible to the naked eye.

The constellation *Gemini* is situated north-east from Orion, and almost due east from the Pleiades, and is one of the signs of the zodiac. It has *Cancer* on the east, *Taurus* on the west, and the *Lynx*, on the north. The orbit of the earth, or the apparent circle described by the sun in his annual course, passes through the middle of this constellation. From the 21st of June till the 23d of July, the sun passes through this sign, but the stars of which it is composed are then invisible, being overpowered by the superior brightness of the solar rays. This constellation is easily distinguished by two brilliant stars, denominated *Castor* and *Pollux*, which are within five degrees of each other. *Castor*, a star of the first magnitude, is the northernmost of the two; and *Pollux*, a star of the second magnitude, is situated a little to the south-east of it. Castor is found by the telescope to be a double star, the smaller one being invisible to the naked eye; and, from a long series of observations, it is found that the smaller star is revolving around the larger with a slow motion, and that a complete revolution will occupy more than 300 years. About twenty degrees south-west of Castor and Pollux are three small stars, nearly in a straight line, and about three or four degrees distant from each other. The southernmost of the three lies nearly in a line with Pollux and the star *Betelguese*, in the constellation of Orion, but somewhat nearer to Betelguese than to Pollux. These stars, in the hieroglyphic figure of Gemini, form the feet of the twins.

Directly south of Gemini is the constellation of *Canis Minor*, or the Lesser Dog. It is situated about mid-way between Gemini and *Canis Major*, or the Greater Dog, and has *Hydra* on the east, and Orion on the west. It consists of only about fourteen stars visible to the naked eye, the principal of which is *Procyon*, a bright star between the first and second magnitude. It is almost directly south from Pollux, and distant from it about twenty-four degrees. The next brightest star in this constellation, which is considerably smaller than Procyon, is called *Gomelza*, and is situated about four degrees north-west of Procyon.

South by west of Canis Minor, at the distance of nearly thirty degrees, is *Canis Major*, or the Greater Dog. It is south-east from the belt of Orion, and due east from the constellation of *Lepus*, or the Hare, at the distance of ten degrees. Canis Major is easily distinguished by the brilliancy of its principal star, *Sirius*, which is apparently the largest and brightest fixed star in the heavens, so that it is generally considered as one of the nearest of these distant orbs, though its distance from the earth is computed at not less than *twenty billions* of miles; and a cannon ball, moving over this immense space at the rate of nineteen miles a minute, would require more than two millions of years before it could reach this distant orb. Sirius is south by east of Betelguese in the left shoulder of Orion, at the distance of twenty-seven degrees, and south-east from the lower star in the belt, at the distance of twenty-three degrees. A line drawn through the three stars which form the belt, towards the south-east, leads the eye directly to Sirius, which, at the period and hour we have stated, is about twelve degrees above the south-easterly point of the horizon; a line drawn from Betelguese south-east towards Sirius, and thence to the north-east meets Procyon in Canis Minor, and continued nearly due west, it again meets Betelguese, so that these three stars seem to form a large triangle, which is nearly equilateral. Another triangle is formed by drawing a line eastward from Betelguese to Procyon, as a base, from Procyon straight north to Pollux, and from thence again south-west to Betelguese, which forms a right-angled triangle, having the right angle at the star Procyon, and the line extending from Pollux to Betelguese forms the hypothenuse.

In order to render these descriptions more definite, I have sketched in Plate I. a small map of this portion of the heavens, in which the principal stars in the constellations above described are represented. The *left*-hand side of this map represents the *east*; the *right*-hand side the *west*; the lower part, the south; and the upper part the north, or higher portion of the heavens. When used so as to compare it with the real firmament, the observer is supposed to have his face directed

chiefly to the south and the south-eastern parts of the sky. He may then easily distinguish the principal stars laid down in it by the following directions:—A line drawn from *A* to *B*, at the top of the map, passes through the star *Castor* in Gemini, which is near the left-hand side. A line drawn from *C* to *D*, passes through *Pollux* in the same sign, which is four or five degrees to the south-east of Castor; it likewise passes near *Auriga*, a star of the second magnitude, in the constellation of the *Wagoner*, which is represented near the middle of the line Almost directly north from Auriga, at the distance of seventeen degrees, is the star *Capella*, in the same constellation, which is one of the brightest stars in the heavens next to Sirius. It is about twenty-eight degrees north-east from the Pleiades, but is beyond the northern limits of the map. A line drawn from *E* to *F*, passes through *Aldebaran*, or the Bull's Eye, and the Hyades; north-west of which is the Pleiades, or seven stars, near the north-west part of the map. A line drawn

## PLATE I.

REPRESENTING A PORTION OF THE SOUTHERN PART OF THE HEAVENS, ABOUT THE MIDDLE OF JANUARY.

from *G* to *H*, passes through the star *Betelguese*, in the east shoulder of Orion; the line from *I* to *K*, passes through *Bellatrix*, in the west shoulder, a star of the second magnitude, somewhat less brilliant than Betelguese, and likewise passes through *Procyon*, in Canis Minor, which appears near the left side of the map: and the line from *L* to *M* passes through the middle star of Orion's belt. The line from *N* to *O* passes through *Rigel*, in the left foot of Orion, a star of the first magnitude fifteen degrees south of Bellatrix. The line *P Q* passes through *Saiph*, a star of the third magnitude, in Orion's right knee, eight and a half degrees east of Rigel. The two form the lower end of the parallelogram of Orion. The line *R S* passes through the star *Sirius*, in in Canis Major, which is east by south from Saiph, at the distance of fifteen degrees. The small stars to the west, or right hand of Sirius form a part of the constellation of *Lepus*, or the Hare. A line drawn from *T* to *U*, from the northern to the southern part of the map, will point out the position of the

stars here represented with respect to the meridian, at the time these observations are supposed to be made. The stars on the right of this line are west of the meridian, and all those to the left are to the east of it.

By attending to the above directions, and comparing the delineations on the map with the heavens, all the stars and constellations noted above may be readily distinguished. The triangles formed by Betelguese, Procyon, and Sirius, and by Pollux, Procyon, and Betelguese, will likewise be seen on the map, as formerly described, and may be easily traced in the heavens. Although I have fixed on the middle of January, at eight o'clock in the evening, for these observations, yet the same stars may be traced, at different hours, during the months of November, December, January, February, and March. About the middle of November, at midnight, and the middle of December, at ten o'clock, P. M., this portion of the heavens will appear nearly in the same position as here represented. About the middle of February, Orion will be on the meridian about eight in the evening; and in the month of March, at the same hour, considerably to the west of it; but all the adjacent stars and constellations may be traced at this time in the manner already described. The stars and constellations delineated on this map comprehend a space in the heavens extending in breadth, from north to south, about fifty degrees—namely, from thirty-three degrees of north declination to seventeen degrees south; and in length, from west to east, about sixty degrees. The *equator* runs through this portion of the heavens in the direction *a b*, or nearly corresponding to the line *L M*, so that it passes very near to the upper star in the belt of Orion. The degrees of north and south declination* from the equator are marked on the margin.

## PLATE II.

### EXHIBITING A PORTION OF THE CONSTELLATIONS, AS SEEN ABOUT THE FIRST OF SEPTEMBER.

* The *declination* of a heavenly body is its distance north or south from the equinoctial, or equator, and corresponds to *latitude* on the terraqueous globe, which is the distance of a place from the equator. The latitude of a *heavenly body* is its distance north or south of the *ecliptic*, or apparent path of the sun, which forms an angle of 23½ degrees with the equinoctial.

Plate II. represents another portion of the heavens as it appears about the beginning of September. It includes some of the larger stars belonging to the constellations *Cygnus, Lyra, Cerberus, Serpentarius, Aquila, Hercules*, and *Corona Borealis*. At ten o'clock in the evening of the 1st of September, the star Altair, in the constellation of Aquila, or the Eagle, will be nearly on the meridian, at an elevation above the horizon of about forty-six degrees. This star, which is between the first and second magnitude, is situated near the east or left-hand side of the map, near the bottom, and has a small star to the south, and another to the north-west of it. A line drawn from *T* to *U* passes through the star Altair, and a line from *V* to *W* passes through the meridian at the hour supposed.

The seven stars which are nearest Altair, towards the south, and west, and north-west, belong to the constellation of *Aquila*. All the stars on the map which are to the right-hand of Altair, are *west* of the meridian. A line drawn from *X* to *Y*, near the top of the map, passes through *Denib*, a bright star of the second magnitude in the constellation of *Cygnus*, or the Swan, which is the star next the left-hand side, nearly due north from Altair, at the distance of thirty-six degrees; the other four stars adjacent to it belong to the same constellation. A line drawn from *A* to *B* passes through the star *Vega*, or *α Lyræ*, a brilliant star of the first magnitude in the constellation of the *Harp*. The six small stars to the south-east of it likewise belong to this constellation. The stars on the right, or to the westward of Vega, belong chiefly to the constellation of *Hercules*. A line drawn from *C* to *D* passes through the principal star *Corona Borealis*, or the Northern Crown, named *Alphacca*, which is of the third magnitude, and near the right-hand side of the map. The stars north and east from it belong to the same constellation. West from Alphacca is *Mirac*, at the distance of eleven degrees; and south-west of Mirac, at the distance of ten degrees, is *Arcturus*, a bright star of the first magnitude, which is then about eighteen degrees above the western horizon. Both these stars are in the constellation of *Bootes*, but they are not within the limits of the map. A line drawn from *F* to *G* passes through *Ras Algethi*, a star of the second magnitude, and the principal star in the constellation of *Hercules*, which is twenty-five degrees south-east of Corona Borealis. A line from *H* to *I* passes through *Ras Alhague*, a star of the second magnitude in the head of *Serpentarius*. This star is five degrees east by south of Ras Algethi. Most of the other stars to the south and east in the map belong to Serpentarius. Various other remarkable stars may be seen at this time besides those noted in the map, particularly the square of *Pegasus*, or the Flying Horse. About fifty-three degrees nearly east from Altair is *Markab*, a star of the second magnitude; sixteen and a half degrees east of Markab is *Algenib*, another star of the second magnitude; fourteen degrees north of Algenib is *Alpheratz*, and fourteen degrees west of Alpheratz is *Scheat*, both of them stars of the second magnitude. These four stars, of nearly equal magnitudes, form the *Square of Pegasus*, and appear nearly half-way between the eastern horizon and the meridian.

All the stars alluded to above may likewise be seen during the months of July and August, when they will appear in a more *easterly* position than at the time stated above; and in the month of October, at eight o'clock, and in November, at six o'clock in the evening, they will be seen nearly in the positions which have been now represented.

Plate III. represents a view of some of the principal stars around the pole, extending from the polar point, in every direction, about forty-five degrees. In using this map, the observer is supposed to be looking towards the north, in which case, the left hand side of the map is towards the *west*, and the right side towards the *east*. The large star near the centre of the map is the Pole-star, which forms the tip of the tail of *Ursa Minor*, the square of which, and the two other stars in the tail, will be seen ascending from it towards the right hand, when the map is so placed that the 1st of April is at the top. There is only one star of the first magnitude within the limits of this map—namely, *Capella*, the principal star in the constellation of *Auriga*, opposite that part of the map where the month of December is marked. A line drawn from *C* to *D* passes through this star, which is adjacent to the extremity of the map. There are eleven stars of the second magnitude; five in the square and tail of *Ursa Major*, or the Great Bear—namely the two pointers, *Dubbe* and *Merak*, *Phad*, *Alioth*, and *Benetnach*. The others are *Menkalina*, *Etanim*, *Rastaban*, *Algenib*, *Delta Cygni*, and the *Pole-star*. A line drawn from *A* to *B* passes through Dubbe and Merok, and the Pole-star at the centre of the map; and on the other side of the Pole-star it passes through a part of the constellation of *Cassiopeia*—the Pole-star being nearly equidistant between that constellation and the pointers. A line drawn from *E* to *F* passes through *Menkalina*, in the constellation of Auriga, about eight degrees from Capella. A line drawn from *G* to *H* passes through *Delta Cygni*, in the Swan, which is placed at the extremity of the map. A line from *I* to *K* passes through Algenib.

the principal star in the constellation of *Perseus*. A line from *L* to *M* passes through *Etanim*, near the right-hand side of the map, a star of the second magnitude in the constellation of *Draco*, near to which, at the distance of four or five degrees is *Rastaban*, likewise a star of the second magnitude in the same constellation. With two other stars they form a kind of irregular square or trapezium, and, with another small star, they form a figure resembling an italic *V*. When the star Etanim comes to the meridian of London, it is exactly in the zenith of that place, which has rendered it of peculiar utility in certain nice astronomical observations. It is celebrated in modern times as being the star which Dr. Bradley selected to determine, if possible, the *Annual Parallax;* and from his observations of which he deduced the important discovery of the *Aberration of Light*.

Let us now suppose that we are to contemplate the northern part of the heavens about the beginning of *April*, at ten o'clock in the evening. Turning our faces towards the pole-star, or directly north, and holding that part of the map uppermost which is opposite to the beginning of April, those stars which are marked on the *upper* part of the map will appear not far from the zenith, or nearly overhead; those towards the lower part will appear at a low elevation, not far from the horizon; those on the right will appear in the east, and those on the left in the west, at different elevations, are here represented. The two pointers in the Great Bear, which are directly opposite to the 1st of April, will be seen nearly in the zenith, and to point *downwards* to the pole star; and at nearly an equal distance below the pole star, they direct the eye to the constellation *Cassiopeia*, which is conceived to have a certain resemblance to a *chair*, and which appears only a small distance above the northern horizon. To the west or left-hand side of Cassiopeia is the constellation *Perseus*, of which Algenib is the principal star, and which is likewise at a low elevation. To the right, or east side of Cassiopeia, is *Cepheus*—four stars of which, two of the third and two of the fourth magnitude, form a kind of square, or rhombus. The stars farther to the east, and in a more elevated position, belong chiefly to the constellation of *Draco*, or the Dragon. The star *Etanim*, in this constellation, appears nearly due east of the pole star, at the distance of forty degrees. The stars on the western side of the map, or on the left hand, nearly opposite to Etanim, belong to the constellation of Auriga; and those on the upper part are chiefly some of the prominent stars connected with the Great Bear. The bright star Capella appears nearly west by south from the pole-star, at a pretty high elevation, with *Menkalina* a little above it, and to the eastward.

Besides the stars marked on this map, there may be seen, at the same time, several brilliant stars of the first magnitude. Turning the eye east by south, the bright star *Arcturus*, in the constellation *Bootes*, is seen about half-way between the horizon and the zenith. Looking to the north-east, the brilliant star *Vega*, or Lyra, appears elevated twenty degrees above the horizon, in a direction nearly opposite to Capella, in the west. Farther to the north, but not quite so elevated as Lyra, is *Deneb*, in the constellation of the Swan. Turning our eye to the west, Castor and Pollux will be seen about midway between the western horizon and zenith; and further down, near the horizon, almost due west, are Betelguese and Bellatrix, the two stars in the shoulders of Orion, Betelguese appearing the more elevated of the two, the other portions Orion having descended below the horizon, To the south-west, midway between Pollux and the horizon, is *Procyon*, a star of the first magnitude in the Lesser Dog.

Suppose, now, we were to observe the same quarter of the heavens, at the same hour, about the beginning of October. In this case we have only to reverse the map, so that the first of October may be uppermost. At this season, Cassiopeia will appear near the zenith, and the two pointers of Ursa Major will be seen at the opposite side of the pole, at no great elevation above the horizon, Capella will appear towards the east, on the right, at a considerable altitude, and the five stars in the head of Draco considerably to the west, while Algenib, and the other stars in Perseus, will be seen in a high elevation, to the east of Cassiopeia. At this time, likewise, by turning our eyes towards the east and the south, Aldebaran, or the Bull's-eye, in the constellation Taurus, will be seen elevated about twelve degrees above the eastern horizon, about sixteen degrees above which are the Pleiades, or seven stars. The star Altair will appear near the south-west, half-way between that point and the meridian, and *Fomalhaut*, in the Southern Fish, will be seen nearly on the meridian, only five or six degrees above the south point of the horizon.

In like manner, were we wishing to observe the position of the circumpolar stars *at any other hour*, at this period, than ten o'clock P. M., suppose at eight in the evening, we have only to turn the line which marks the beginning of September uppermost instead of October, and the position at that hour will be seen; and if we choose to make our observations at six in the evening we turn the

first of August to the top, allowing two hours, at an average, for every month. If we would inspect their position at twelve midnight, the first of November must be turned round to the top, and so on for any other hour. If we would make our observations in the beginning of January at ten P. M., that point must be turned to the top, and then the two pointers will be seen on the right, straight east of the pole-star, and the other five stars hanging down from them, Cassiopeia nearly straight west, and Capella not far from the zenith. These circumpolar stars may therefore be seen at every season of the year, and their relative positions determined beforehand by simply turning round the map to the month, or day of the month, required, so that that point may be at the top; and although the months are arranged so as to correspond with ten o'clock P. M., yet the positions may be represented for any other hour, according to the directions given above.

The following remarks may be stated in reference to the stars depicted on this map:—

## PLATE III.

### THE NORTH CIRCUMPOLAR STARS.

1. All these stars never set in our latitude, but appear to move round *above* the horizon in circles of which the pole is the centre. As the observer is supposed to be in fifty-two degrees N. latitude, all the stars within 52° of the pole never descend below the horizon. In one part of their diurnal course they appear above the pole, and some of them near the zenith, and in the opposite point they appear below the polar point, and sometimes near the northern horizon. 2. In the higher part of their course they appear to move from east to west, and in the lower part from west to east. Those nearest the pole describe small circles around the polar point, and those at greater distances describe larger circles; but their periods of apparent revolution are exactly the same—namely, twenty-three hours, fifty-six minutes, and four seconds. 3. The stars represented in this map are only those which are most prominent and obvious to the naked eye, in order to prevent confusion, and

that the untutored observer may not be distracted with too many objects at one view. They chiefly consist of stars of the second, third, and fourth magnitudes. 4. In order that the observer may be able readily to estimate the apparent distances of the stars from each other and from the horizon, it may be proper to keep in mind that the distance between the two pointers is exactly five degrees, and between Dubbe (the nearest to the pole) and the pole-star, twenty-nine degrees. By applying these measures by the eye to other stars, their apparent distances may be very nearly estimated. 5. Although I have stated, in general terms, that the pointers come to the southern meridian, or are nearly in the zenith, at ten P. M., *about the beginning* of April, yet it is not before the seventh of this month that they are accurately in this position at ten in the evening; but the difference is not much perceptible by the eye during the course of a week or two, and therefore can lead to no great mistake. 6. If the circle containing the stars were cut out, and surrounded with the circle of months and days, and made to revolve within the circle of hours, it might be made to serve the purpose of an astronomical clock for pointing out the hours of the night, and likewise for showing the positions of the circumpolar stars for any hour of the day or night. 7. The delineations of the apparent distances of the stars on this map are on a scale of only one-half the size of that on which the two preceding map were constructed.

The three preceding views of certain portions of the heavens, partly delineated from actual observation, are intended to convey to general observers a *natural* representation of those quarters of the firmament to which they refer, so that by a little further attention and observation, and an inspection of a celestial atlas, they may acquire a general view of the principal stars and constellations visible in our hemisphere; for on most celestial planispheres and globes there is such a group of eyes, noses, legs, tails, claws, and wings connected with the mythological figures of the constellations, no traces of which can be seen in the heavens, that the learner is sometimes confounded, and can scarcely trace any resemblance between what is depicted on such globes and planispheres and the real aspect of the firmament, the stars appearing, in many instances, as accidental spots, buried, as it were, amidst the group of hieroglyphics with which they are connected.

## CHAPTER II.

### *On the Arrangement of the Stars into Constellations, with Sketches of their Mythological History.*

In order to distinguish the stars from one another, the ancients divided the heavens into different portions or spaces, called *constellations*, or groups of stars. They supposed each group to occupy a space which a lion, a bear, a man, a harp, or other object would fill, if it were there delineated; and hence the different constellations were depicted as if they had borne a resemblance to dragons, dogs, rams, altars, ships, and similar objects, whether imaginary or real. The invention of the constellations, particularly those of the Zodiac, is generally attributed to the Chaldeans or the Egyptians; but most probably the merit, such as it is, is due to the former, although the Egyptians appear, at a very early period, to have derived the knowledge of astronomy from the inhabitants of Chaldea, and imparted it to the ancient Greeks and other nations. The first series of constellations which were formed appear to have been those of the Zodiac. Finding that the year consisted neither of twelve nor of thirteen lunations, in order to know the precise bounds of the annual course of the sun, they were under the necessity of carefully examining what stars were successively obscured in the evening by the motion of that globe, and what stars, after emerging from its rays, showed themselves again before the dawn of day.

Macrobius, an ancient Roman author, and Sextus Empiricus, a Greek writer, have handed down to us the ingenious method which the first astronomers used to determine exactly the course which the sun describes in the heavens, and to divide the year into equal portions, of which the following is a condensed description:

They every day saw the sun and the whole heavens turning round from the east to west. In the mean time they observed that the sun, by a motion peculiar to it, receded, from day to day, from certain stars, and took its place under others, always advancing towards the east. As they found that twelve revolutions of the moon approximated to one revolution of the sun, but that a certain sensible differ-

ence existed, they wished that they might have twelve divisions of the year, which might be *exactly* equivalent to the year itself. For this purpose they took two brass open vessels, the one pierced at the bottom, and the other without any orifice below. Having stopped the hole of the first, they filled it with water, and placed it so that the water might run out into the other vessel the moment the cock should be opened. This done, they observed in that part of the heavens where the sun has its annual course, the rising of a star, remarkable either for its magnitude or its brightness, and at the critical instant it appeared on the horizon they began to let the water flow out of the upper vessel into the other, during the rest of the night and the whole following day, till the very moment when the same star began to appear anew on the horizon. The instant it was again seen they took away the under vessel, and threw the water that remained in the upper on the ground. The observers were thus sure of having one revolution of the whole heaven, between the first rising of the star and its return. The water which had flowed during that time now afforded them the means of measuring the duration of one whole revolution of the starry firmament, and of dividing that duration into several equal portions. They then divided the water of the under vessel into twelve parts, *perfectly equal*, and prepared two other small vessels capable of containing exactly one of these portions, and no more. They again poured into the great copper vessel the twelve parts of water all at once, keeping the vessels shut. They then placed under the cock, still shut, one of the two small vessels, and another near it to succeed the first as soon as it should be full. All these preparations being ready, the next night they observed that part of the heavens towards which they had remarked the sun took his course, and waited for the rising of the constellation which has since been called *Aries*. The instant Aries appeared, and they saw the first star of its ascending, they let the water run into the little measure. As soon as it was full they removed it, and threw the water out. In the mean time they put the other empty measure under the fall. They observed accurately all the stars that rose during all the periods which the measure took in filling, and that part of the heavens was terminated in their observations by the star which appeared last on the horizon the moment the measure was just full. In like manner they proceeded with the other vessel alternately, till the two small vessels were three times filled, which marked out six divisions, or one-half of the course of the sun in the heavens. They were then forced to defer the observation and measurement of the other half of the firmament till the opposite season of the year, when they proceeded as before.

Having in this manner determined the twelve divisions of the heavens, and marked the clusters of stars peculiar to each, they proceeded to give them names, and in general termed them the stations or *houses* of the sun, three of which were assigned to each season. The particular names given to each of the twelve constellations of the Zodiac are generally supposed to refer to certain circumstances peculiar to the different months. As the Chaldean observers seem to have been of opinion that there were, during the spring, no productions more useful than lambs, calves, and rams, they gave the constellations through which the sun passes during that season the names of the three animals by which they were most enriched. The first was named *Aries*, or the Ram; the second *Taurus*, or the Bull; and the third *Gemini*, or the Twins,—that is, the two goats, which commonly bring forth two young at a time. The Greeks afterwards represented them by Castor and Pollux, two twin brothers, sons of Jupiter, by Leda, the wife of Tyndarus, and as such are represented on our globes. Having remarked that there was a point to which the sun approached when passing these signs, but which it never went beyond, and that it afterwards receded from that point for six months together, this retreat of the sun backwards led them to distinguish it by the name of an animal which walks backwards, and hence it was denominated *Cancer*, or the Crab. As the heats in the next month (July) are most intense, they compared them to the raging and fierceness of a lion, and hence they called the sign *Leo*, that is, the Lion. As in the next month harvest commences, and as young girls were generally set to *glean* in the fields, they denominated the sign corresponding to this month *Virgo*, or the Virgin, which is represented by the figure of a young woman holding an ear of corn.

The perfect equality of days and nights which happens when the sun quits the sign of Virgo, caused astronomers to give the next sign the name of *Libra*, that is, the Balance, poised so as to represent equal day and night. The frequent diseases which are produced in consequence of the sun retiring to the south procured the next sign the name of *Scorpio*, or the Scorpion, because it is mischevious, and drags after it a sting and venom. When harvest is over, and the fields cleared of the crops, then is the season for hunting, and therefore the sign in which the sun enters at that time has obtained the name of *Sagittarius*, that is, the Archer, or Huntsman. The next constellation, *Capricorn*, had its origin from the

wild goat, whose nature being to seek its food from the bottom to the top of mountains, was considered emblematical of the ascent of the sun from the lowest point of its course, in the beginning of this sign, to its highest pitch or summit in the summer solstice, when it enters the sign Cancer. The next sign is called *Aquarius*, or the Water-bearer, emblematical of the rains which generally fall at this season of the year; and the last sign is named *Pisces*, or the Fishes, which name seems to have been given because at the time when the sun enters it, fishes are then considered as fattest and most in season for use.

Such were the names and symbols which the ancients appropriated to that great circle or zone of the heavens through which the sun, moon, and planets appeared to move. As the names of ten of these signs or constellations are borrowed from several animals, astronomers gave the annual zone which they compose the name of *the Zodiac*, that is, the circle of animals, from the Greek word, ζωον, an animal. By this division of the heavens, mankind acquired a new method of measuring time, and of regulating all their labours. From the knowledge of the Zodiac they obtained an exact knowledge of the year and of its several sub-divisions, and the periods when sowing ought to commence, and when the fruits of harvest might be expected to arrive at maturity. When, after the setting of the sun, they saw the stars of the sign *Aries* ascend the opposite horizon, and distant from the sun by one-half of the sphere of the heavens, they then knew that the sun was under the sign *Libra*, which, being the seventh of the celestial signs, was distant from the first by one-half of the whole Zodiac. When, at the approach of day, they saw, in the middle of the firmament, or on their meridian, at an equal distance from east and west, the principal star of the sign *Leo*, they understood that the sun, then about to rise, was at the distance of *three* signs from Leo, and removed towards the east one-fourth part of its circle. Thus, without seeing the stars, which were obscured and overpowered by the sun's rays as he passed through them, they could say, with a perfect assurance, "the sun is now in *Scorpio*, and in two months hence the shortest day will arrive." On the sight of a single constellation, placed either in the eastern, western, or middle part of the heavens, they could immediately tell in what sign the sun was, how far the year was advanced, and what kinds of labour were requisite to be performed. It is therefore to astronomy we are originally indebted for our knowledge of the length of the year, and the commencement of its different seasons.

The ancients next proceeded to arrange into constellations the other groups of stars which were situated to the north and south of the Zodiac. In forming this arrangement they proceeded on principles similar to those by which they had delineated the signs of the Zodiac. They conceived the different groups as if they bore a certain resemblance to birds, beasts, serpents, or to certain imaginary beings, and gave them names corresponding to such conceptions. This they seem to have done for the sake of assisting the memory and imagination in forming a general idea of the forms and the relative positions of the several clusters of stars, and to enable the observer more readily to distinguish and to point out any particular star; but it would be too tedious, and would convey little profitable instruction, to inquire into the reasons of the emblematical figures they adopted, or to attempt a detailed view of their mythological history.

The following table contains a list of all the constellations, ancient and modern, with the number of stars in each, as stated in the *Historia Celestis* of *Flamstead*, formerly Royal Professor of Astronomy at Greenwich. The first column contains the *name* of the constellation, the second column the number of stars it contains, and the third column the principal stars and their magnitudes. The number 1, expresses stars of the first magnitude; 2, those of the second magnitude, &c.

## NORTHERN CONSTELLATIONS.

| Name. | No. of Stars. | Principal Stars. |
|---|---|---|
| Ursa Minor—the Little Bear | 24 | Pole star, 2. |
| Ursa Major—the Great Bear | 87 | Dubhe, 1; Alioth, 2. |
| Draco—the Dragon | 80 | Rastaben, 2. |
| Cepheus [East of Draco] | 35 | Alderamin, 3. |
| Bootes—the Herdsman | 54 | Arcturus, 1; Mirac, 3. |
| Corona Borealis—the Northern Crown [East of Bootes] | 21 | Alphecca, 2. |
| Hercules, with Cerberus | 113 | Ras Algethi, 2 |
| Lyra—the Harp | 21 | *Vega*, or Lyra, 1. |
| Cygnus—the Swan | 81 | Deneb, 2. |

| Name. | No. of Stars. | Principal Stars. |
|---|---|---|
| Cassiopeia—Lady in her chair | 55 | Schedir, 3. |
| Perseus, and Head of Medusa | 59 | Algenib, 2; Algol, 2. |
| Auriga—the Wagoner | 66 | Capella, Alajoth, 1. |
| Serpentarius—Serpent Bearer | 74 | Ras Alhague, 2. |
| Serpens—the Serpent | 64 | |
| Sagitta—the Arrow [N. of Aquila] | 18 | |
| Aquila and Antinous—the Eagle, &c. | 71 | Altair, 1 or 2. |
| Delphinus—the Dolphin | 18 | |
| Equuleus—the Horse's Head | 10 | |
| Pegasus—the Flying Horse | 89 | Markab, 2; Scheat, 2. |
| Andromeda | 66 | Alamak, 2; Mirack, 2 |
| Triangulum—the Triangle | 16 | |
| Camelopardalis—Camelopard | 58 | |
| Leo Minor—the Little Lion | 53 | |
| Coma Berenices—Berenices' Hair [North of Virgo] | 43 | |
| Vulpecula et Anser—the Fox and Goose [South of Cygnus] | 35 | |
| Lacerto—the Lizard [East of Cygnus] | 16 | |
| Scutum Sobieski [North of Sagittarius] | 8 | |
| Canis Venatici—the Grayhounds | 25 | |
| Lynx | 44 | |
| Cerberus | 4 | |
| Mons Menelaus [S.-E. of Bootes] | 11 | |
| Taurus Poniatowski—the Bull of Poniatowski [W. of Aquila] | 7 | |
| Musca—the Fly [N. of Aries] | 6 | |
| Tarandus—Reindeer [at N. Pole] | 12 | |
| Total number of stars in the Northern Constellations | 1444 | |

## SOUTHERN CONSTELLATIONS.

*These Constellations marked thus † never rise in N. latitude 52 degrees.*

| Name. | No. of Stars. | Principal Stars. |
|---|---|---|
| Cetus—the Whale | 97 | Menkar, 2; Mira, 2. |
| Orion | 78 | Betelguese, 1; Rigel, 1. |
| Eridanus—the River Po | 84 | Achernar, 1. |
| Lepus—the Hare [S. of Orion] | 19 | |
| Canis Major—the Great Dog | 31 | Sirius, 1. |
| Canis Minor [N. of Monoceros] | 14 | Procyon, 1. |
| Argo Navis—the Argo | 64 | Canopus, 1; Naos, 2. |
| Hydra—the Serpent | 60 | Cor Hydræ, 1. |
| Crater—the Cup [S. of Virgo] | 31 | Algorab, 3. |
| Corvus—the Crow [S. of Virgo] | 9 | Alkes, 3. |
| Centaurus—the Centaur | 35 | |
| Lupus—the Wolf | 24 | |
| Ara†—the Altar | 9 | |
| Corona Australis—Southern Crown | 12 | |
| Piscis Australis [S. of Aquarius] | 24 | Fomalhaut, 1. |
| Columbo Noachi—Noah's Dove | 10 | |
| Rober Caroli† [E. of Argo Navis] | 12 | |
| Grus†—the Crane | 13 | |
| Phœnix† | 12 | |
| Indus†—the Indian | 12 | |
| Pavo†—the Peacock | 14 | |
| Apus†—the Bird of Paradise | 11 | |
| Apis Musca† Australis, | 4 | |

| Name. | No. of Stars. | Principal Stars. |
|---|---|---|
| Triangulum Australis† [South Triangle] . . | 5 | |
| Piscis Volans†—the Flying Fish . . . . . | 8 | |
| Chameleon† [near the S. Pole]. . . . . . | 10 | |
| Dorado†—the Sword Fish . . . . . . . . | 6 | |
| Toucan†—the American Goose . . . . . | 9 | |
| Hydrus†—the Water Snake . . . . . . | 10 | |
| Sextans—the Sextant [S. of Leo] . . . . | 41 | |
| Monoceros—the Unicorn . . . . . . . . | 31 | |
| Crux—the Cross† . . . . . . . . . . . | 6 | |
| The Sculptor's Apparatus . . . . . . . . | 12 | |
| Circinus†—the Compasses . . . . . . . . | 7 | |
| Brandenburgium Sceptrum [S. W. of Orion] . | 6 | |
| Equuleus Pictorius . . . . . . . . . . | 8 | |
| Fornax Chemica . . . . . . . . . . . . | 14 | |
| Horologium†—the Clock . . . . . . . . | 12 | |
| Mons Mensa†—the Table Mountain . . . | 30 | |
| Machina Pneumatica—the Air Pump . . . | 24 | |
| Norma, or Euclid's Square . . . . . . . . | 12 | |
| Octans Hadleianus†—Hadley's Octant . . . | 43 | |
| Pyxis Gautica—Mariner's Compass . . . . | 8 | |
| Reticula Rhomboidalis† . . . . . . . . . | 10 | |
| Telescopium†—the Telescope . . . . . . | 9 | |
| Sculptorio†—the Engraver's Tools . . . . | 16 | |
| Microscopium—the Microscope . . . . . | 10 | |
| Total number of stars in the Southern Constellations . . . . . . . . . | 1027 | |

## ZODIACAL CONSTELLATIONS.

| Name. | No. of Stars. | Principal Stars. |
|---|---|---|
| Aries—the Ram . . . . . . . . . . . | 66 | α Arietis, 2. |
| Taurus—the Bull. . . . . . . . . . . . | 141 | Aldebaran, 1; Pleiades. |
| Gemini—the Twins . . . . . . . . . . | 85 | Castor, 1; Pollux, 1. |
| Cancer—the Crab . . . . . . . . . . | 83 | Acubens, 3. |
| Leo—the Lion. . . . . . . . . . . . . | 95 | Regulus, 1; Denebola, 2 |
| Virgo—the Virgin . . . . . . . . . . | 110 | Spica Virginis, 1. |
| Libra—the Balance . . . . . . . . . . | 51 | Zubeneschamale, 2. |
| Scorpio—the Scorpion . . . . . . . . | 44 | Antares, 1. |
| Sagittarius—the Archer . . . . . . . . | 69 | |
| Capricornus—the Goat . . . . . . . . | 51 | |
| Aquaris—the Water Bearer . . . . . . | 108 | Scheat, 3. |
| Pisces—the Fishes . . . . . . . . . . | 113 | |
| Total number of stars in the Zodiac . . | 1016 | |
| Total number of stars in all the Constellations . . . . . | | 3487 |

Thus all the visible stars in the firmament have been arranged into ninety-four constellations, of which forty-eight were formed by the ancients, and the rest within the last two or three hundred years. Of the stars above enumerated, there are about 17 of the first magnitude, 76 of the second, 223 of the third, and the remainder of the fourth, fifth, and sixth magnitudes. The different classes of magnitudes are intended to express their apparent brightness. The brightest stars are said to be of the first magnitude; those which appear next in brightness, or inferior to the first, are classed in the second magnitude; and so on down to the sixth magnitude, which comprises the smallest stars visible to the naked eye in the clearest night; though there are but few eyes that can distinguish those which belong to the sixth magnitude. All the stars beyond these limits come under the general denomination of *Telescopic stars;* and with the most powerful telescopes, stars may be perceived of all classes, from the sixth to the sixteenth order of magnitudes. Every increase in the power of these instruments brings into view innumerable multitudes of

those orbs which were before invisible, so that no definite limits can be assigned to the apparent brightness or magnitude of the stars. This classification into magnitudes, however, as it is entirely arbitary, so it is extremely indefinite, and can convey no very accurate ideas even of their *apparent* brightness or intensity of light. This consideration has led some eminent astronomers to endeavour to estimate the apparent brightness of each star by experiments made with the photometer. From various experimental comparisons of this kind, the late Sir Wm. Herschel deduced the following conclusions:

| | Magnitude; | | |
|---|---|---|---|
| Light of a star of the average | 1st | - — | 100 |
| | 2d | - — | 25 |
| | 3d | - — | 12 |
| | 4th | - — | 6 |
| | 5th | - — | 2 |
| | 6th | - — | 1 |

So that the light of a star of the second magnitude is one-fourth of that of a star of the first magnitude; the light of one of the third, one eight; of the fourth, one sixteenth; of the fifth, one fiftieth; and of the sixth, only one-hundredth part. Sir John Herschel informs us that, from his own experiments, he has found that the light of *Sirius*, the brightest of all the fixed stars, is about 324 times that of an average star of the sixth magnitude.

It may be proper to observe that the stars specified in the statements inserted above are not all visible to the naked eye, nearly two-thirds of them being perceptible only by the telescope; but they are those stars whose latitudes and longitudes, and whose right ascensions and declinations, have been accurately determined. They form only *a very small proportion* of those which are found to exist in the most distant regions of the firmament; for by powerful telescopes there have been explored, in a single speck of the heavens, a number which far exceeds that of all the visible stars in the sky; and catalogues have been formed in modern times which comprise from fifty to a hundred thousand of these luminaries.

The first astronomer, so far as we know, who attempted to take a catalogue of the stars, was *Hipparchus* of Rhodes, who flourished about 120 years before Christ. Having observed a new star, which he had never seen before, he began to doubt whether there might not be changes occasionally taking place among these luminaries, and therefore commenced making a catalogue of them, noting down the position and magnitude of each star, with the view that, if any new stars should again appear, or any of those observed by him should increase or diminish in magnitude, or totally disappear, such changes might be known to those who should live in future ages. This catalogue, which was handed down to us by Ptolemy, an ancient Egyptian astronomer, has been of special use to modern astronomers, both in determining the rate of the precession of the equinoxes, and in proving that certain stars which then existed are no longer to be seen in the heavens; thus indicating that changes and revolutions are taking place among the distant bodies of the universe. The catalogue of Hipparchus contained a description of the places of 1026 stars. The Arabians are the next whom history represents as having attempted to form a descriptive catalogue of the stars. This was effected by *Ulug Beigh*, the grandson of Tamerlane, from his own observations made at Samarcand, whose catalogue contains 1022 stars. Tycho Brahe, the celebrated Danish astronomer, who lived in the sixteenth century, by means of the large and accurate instruments he invented, formed a catalogue of 777 stars, which are considered as superior in correctness to those of Hipparchus and Ulug Beigh. He was prompted to this laborious undertaking by the sudden appearance of a new star in Cassiopeia in the year 1572, which shone with the brilliancy of Venus, and was visible even at noonday. *Bayer* soon after published a catalogue of 1160 stars, in which he introduced the practice distinguishing the stars by the letters of the Greek alphabet. All the catalogues now mentioned were formed before the telescope was invented, and contained nearly all the stars which could be perceived by the unassisted eye. Soon after the invention of the telescope, in the beginning of the seventeenth century, the celebrated Hevelius composed a catalogue of 1888 stars, of which 1553 were observed by himself, and their places computed for the year 1660. But some of our modern observers of the heavens have published catalogues which contain the positions of many thousands of stars, besides multitudes of nebulæ, of various descriptions, double, triple, and quadruple stars, and various other celestial phenomena.

The division of the heavens into constellations, and the names and figures by which they are distinguished, seem to have been of a very ancient date. Job, who is supposed to have lived in a period prior to that of Moses, refers to some of them by the same names which they still bear. "Canst thou bind the sweet influences of *Pleiades*"—or the seven stars,—"or loose the bands of Orion?" that is, the *belt* of Orion, which consists of three equidistant stars in a straight line. "Canst thou bring forth Mazzaroth in

his season? or canst thou guide Arcturus with his sons?" Arcturus is a bright star of the first magnitude in the constellation of Bootes, and is here put for the constellation itself. The expression "his sons" is supposed to refer to *Asterion* and *Chara*, the two Grayhounds, with which he seems to be pursuing the Great Bear around the North pole, in the diurnal revolution of the heavens. *Mazzaroth* is generally supposed to refer to the twelve signs of the zodiac, which, by their appointed revolutions, produce the succession of day and night, and the seasons of the year. In another part of this book, Job, when filled with profound reverence of the majesty of God, declares that He alone "spreadeth out the heavens, and maketh Arcturus, Orion, and the Chambers of the South." The prophet Amos, who lived 800 years before the Christian era, alludes to the same objects in the fifth chapter of his prophecy—"Ye who turn judgment to wormwood, and leave off righteousness in the earth, seek him who maketh the seven stars and Orion, who turneth the shadow of death into morning, and maketh the day dark with night; that calleth for the waters of the sea, and poureth them out upon the face of the earth: the Lord of Hosts is his name."

The names of the constellations, and the hyeroglyphic figures by which they are represented, appear, however, to have had their origin in superstitious and idolatrous notions. The Egyptians, it is well known, worshipped the host of heaven under the figures of most of the animals which represent the celestial constellations, particularly the signs of the Zodiac. They imagined the sun, which they called *Osiris*, to be a proper representative of the Spirit of Nature, or the Supreme Being, who, like the sun, appears every where present, exercising his influence over the universe. The moon, as she receives her light from the sun, was looked upon as a female divinity, and called *Isis*,—which goddess was made to signify universal nature considered as passive, and susceptible of various impressions, forms, and qualities. They found, or imagined they found, in various animals some properties or qualities corresponding to the motions, appearances, or influences of the sun, moon, and stars. This induced them not only to use those animals in their hieroglyphic representations of their deities, but also to pay them honours. Thus, by the *Ram*, a prolific animal, they represented the genial, fertilizing influence of the sun in spring; and by the hot and furious *Lion*, his violent scorching heat in the summer; and the Bull was an emblem of the various powers of the sun in forwarding the business of agriculture, in which this animal was of particular service. As the overflowing of the Nile is particularly beneficial to the land of Egypt, and as that river was observed to begin to swell at the rising of Sirius, or the Dog Star, so they had a special veneration for that orb, as if its divine influence had contributed to that fertility which was produced by the inundation of the Nile. That the Egyptians worshipped all the animals depicted on the Zodiac, and those which represent several of the other constellations, is proved by the testimony of several ancient authors, particularly Herodotus, who says that "in Egypt all sorts of beasts, whether wild or tame, were accounted as sacred, and received divine honours." And it is not improbable that this worship of the host of heaven, through the hieroglyphics of various animals, was a general practice during the abode of the children of Israel in that country, and that the following admonition of Moses has a reference to this circumstance:—"Take heed lest ye corrupt yourselves and make you a graven image, the similitude of any figure, the likeness of any male or female, the likeness of any beast that is on the earth, the likeness of any fowl that flyeth in the air, the likeness of any thing that creepeth upon the ground, the likeness of any fish that is in the waters beneath the earth; and lest thou lift up thine eyes to heaven, and when thou seest the sun, and the moon, and the stars, even all the host of heaven, shouldest be driven to worship them and serve them, which the Lord thy God hath divided unto all nations under the whole heaven. But the Lord thy God hath taken you, and brought you forth out of the iron furnace, even out of Egypt." The reference here made to their being brought out of Egypt seems evidently intended to put the Israelites in mind of their deliverance *from the idolatrous practices* of the inhabitants of that country, as well as from the slavery to which they had been subjected, and consequently implies that the Egyptians indulged in the superstitious worship to which we have alluded.

As it is the practice of astronomers to denote the relative apparent magnitudes of stars in each constellation by the letters of the Greek alphabet, the whole of this alphabet is here inserted, that the unlearned reader may be enabled to distinguish the different characters, and the order in which they follow each other.

The first letter of the Greek Alphabet $\alpha$, denotes the largest or brightest star in each constellation. Thus, $\alpha$ Lyræ is the brightest star in the constellation of Lyra, or the Lyre; $\beta$ Lyræ, the star next in brightness to alpha; and so on throughout all the letters of the Greek alphabet. When the number of stars to be distinguished in any constellation is

greater than the number of letters in the Greek alphabet, astronomers have recourse to the letters of the English alphabet, and distinguish the remaining stars, according to their apparent brilliancy, by the letters a, b, c, d, &c.; and if more stars still remain to be distinguished, they resort to numerals,—thus, $a^4$, $d^4$, &c. From this mode of distinguishing the apparent magnitude of the stars, the reader will easily perceive that those stars which are distinguished by the first letters of the Greek alphabet are the largest in any particular constellation, while those which are marked with letters towards the close of the alphabet are among the smaller stars.

## GREEK ALPHABET.

| Greek Characters. | Names. | Greek Capitals. | Roman Characters. |
|---|---|---|---|
| α | Alpha. | Α | a |
| β | Beta | Β | b |
| γ | Gamma | Γ | g |
| δ | Delta | Δ | d |
| ε | Epsilon | Ε | e, short |
| ζ | Zeta | Ζ | z |
| η | Eta | Η | e, long |
| ϑ θ | Theta | Θ | th |
| ι | Iota | Ι | i |
| κ | Cappa | Κ | k |
| λ | Lambda | Λ | l |
| μ | Mu | Μ | m |
| ν | Nu | Ν | n |
| ξ | Xi | Ξ | x |
| ο | Omicron | Ο | o, snort |
| π | Pi | Π | p |
| ρ | Rho | Ρ | r |
| σ ς | Sigma | Σ | s |
| τ | Tau | Τ | t |
| υ | Upsilon | Υ | u |
| φ | Phi | Φ | ph |
| χ | Chi | Χ | ch |
| ψ | Psi | Ψ | ps |
| ω | Omega | Ω | o, long |

## CHAPTER III.

### *On the Propriety of Adopting a more Natural Arrangement and Delineation of the Starry Groups.*

The figures of the celestial constellations to which we have now adverted are still depicted in our celestial globes and planispheres, and present, in my opinion, a very awkward and *unnatural* representation of the starry heavens. It is rather a strange circumstance, that for a period of more than two thousand years the firmament has been contemplated, and the arrangements of the bodies it contains studied, through the medium of bears, serpents, lizards, rams, whales, centaurs, dolphins, flying horses, three-headed dogs, hydras, dragons, and many other grotesque and incongruous figures. The sublime wonders of the evening sky have thus been associated with a group of mean, ridiculous, and imaginary objects, of which we have scarcely any prototype in nature, and in which there is not the least shadow of a resemblance to the objects they are intended to represent. When the young student of astronomy wishes to distinguish particular assemblages of suns and systems of worlds, he is required to connect them in his imagination with wolves, lions snakes, and numerous fantastical figures, which are bent and twisted into unnatural shapes, which have as little resemblance to the objects in the heavens as the gloom of midnight to the splendours of the meridian sun. Such representations have a tendency to convey to juvenile minds a mean idea of the most august bodies in nature, and of the ample spaces which surround them, and in which they perform their revolutions.

The terms used in any science, the mode of communicating its instructions, and the delineations which such instructions require, ought undoubtedly to be accommodated to the discoveries which have been made in the course of ages, and to the present state and objects of that science; and unless we can show that the terms and figures to which I allude are the best calculated to the present state and objects of astronomical science, and fitted to assist the student in forming natural and correct ideas of the arrangement of the celestial orbs, it is expedient that some change and improvement in this respect should be adopted, in accordance with the new modifications and arrangements which have been introduced into other departments of science. The propriety of introducing some changes in delineating the constellations, and in their nomenclature may perhaps appear from the following considerations:

1. The natural and hieroglyphic figures now in use have no resemblance to the groups of stars they are intended to represent. What resemblance, for example, exists between an eagle, a wolf, a centaur, a flying-fish, or Hercules with his club—and the constellations which bear their names and are attempted to be delineated by their figures? Even when imagination has stretched itself to the utmost

in order to fancy a resemblance, it is obliged to represent such creatures in the most unnatural positions; and after all, it is found impossible to bend and twist their wings, and legs, and tails, and claws, in such a manner as to take in all the stars in the group, some pretty conspicuous ones, being still left unformed in the intermediate spaces. Besides, the discovery of new stars by the telescope has now completely deranged the figures of the ancient constellations; so that however much the legs, arms, and feet of the figures may be twisted, they cannot be made to coincide with hundreds of stars which are known to exist. The only constellations which may be said to bear a very rude resemblance to the natural figures are Orion and Ursa Major; but even in these the resemblance is very distant. Hence what is commonly called a *bear* is also conceived to resemble a *plough* and a *wagon*, and is, by the vulgar, distinguished by these names. Hence, also, different nations represent the same constellation by different figures:—thus, instead of our hieroglyphic delineations, the Hindoos have bespattered the firmament with bedsteads, dogs' tails, ear-rings, couches, elephants' teeth, cats' claws, red saffron, children's pencils, lions' tails, festoons, wheels, razors, pieces of coral, pearls, and other whimsical objects equally appropriate.*

In a judicious comparison of the figures of the different clusters of stars with any other object, for the purpose of a name or reference, the figure of the particular cluster ought first to be accurately considered, and then an object, having as near a relation to it as possible, should be fixed upon as its representation. But an order exactly the reverse of this seems to have been adopted by the ancients in their arrangement and nomenclature of the constellations. They first fixed upon the heroes, animals, and mythological figures which they intended to place in the celestial vault; and then attempted, if possible, to bend the clusters of stars to correspond with them —a most absurd, unscientific and unnatural procedure. And shall all succeeding astronomers in every nation tacitly give their approbation of such rude and injudicious arrangements, as if they were unqualified for forming a more scientific and definite outline of the sublime spaces of the firmament?

2. The figures now in use tend to convey a mean idea of the objects they are intended to represent. When the stars were considered as merely a number of tapers or studs fixed in the vault of heaven, solely for the purpose of shedding a few glimering rays on the earth and adorning the canopy of our habitation, it might not appear quite so incongruous to represent their different groups by "corruptible men, and birds, and four-footed beasts, and creeping things." But now that the astronomer views the stars as so many suns and systems of worlds, dispersed through the immensity of space, the association of such august objects with representations so silly and whimsical as the mythological figures delineated on our globes, produces not only a ludicrous effect by the greatness of the contrast, but, for the same reason, tends to lessen the idea of sublimity which naturally strikes the mind on the contemplation of such a stupendous scene. Every one knows how much things great and noble are debased by being placed in intimate connexion with little and ignoble objects, and must feel the force of this association in the following lines of Hudibras:

> "And now had Phœbus in the lap
> Of Thetis taken out his nap;
> And like a lobster boil'd, the morn,
> From black to red began to turn."

Again—

> "Cardan believed great states depend
> Upon the tip of the Bear's tail's end;
> That as she whisk'd it towards the sun,
> Strew'd mighty empires up and down"

Again—

> Who made the *Balance*, and whence came
> The *Bull*, the *Lion*, and the *Ram*?
> Did not we here the *Argo* rig?
> Wake Berenice's Periwig?
> Whose livery does the *Coachman* wear?
> Or who made *Cassiopeia's* chair?
> And therefore as they came from hence,
> With us may hold intelligence."

Such an effect the celestial hieroglyphics have a tendency to produce, when placed in association with the august objects of the sky.

3. They tend to lead us back to the dark and rude ages of the world, and to familiarize our minds to those crude, chimerical, and absurd conceptions which ought now to descend into oblivion. The signs of the zodiac and most of the other constellations were invented by the Egyptians or Chaldeans to perpetuate the memory of some of their rude and barbarous heroes, to assist them in their absurd and idolatrous worship, or to serve the foolish and impious pretentions of astrology. In neither of these respects can the celestial hieroglyphics be interesting or instructive to the modern student of astronomical science; but they are, in almost every point of view, associated with opinions, practices, and representations, which deserve the most marked reprobation: they also distract the attention by turning it aside

* See "Asiatic Researches," Vol. ii. Art 16—Antiquity of the Indian Zodiac.

from the direct objects of the science to the investigation of their fabulous history. How ridiculous the story of Calisto and her son Arces, whom the rage of Juno turned into bears, which now circulate about the north pole!—the story of Medusa, whose golden hair Minerva turned into snakes, and of the winged horse which sprung from the blood which gushed out in striking off Medusa's head!—the story of Orion, who was produced from the hide of an ox moistened with wine!—the story of the Dragon which guarded the golden apples in the garden of the Hesperides, and was taken up to heaven and made a constellation on account of his faithful services!—the story of Andromeda, of the Swan, of Perseus, and a hundred others of a similar description!

Such is the heaven of the pagans—a common receptacle of all ranks of creatures, real and imaginary, without distinction or order; a wild miscellany of every thing that is false, grotesque, and chimerical. Such fantastical groups, which occupy the "houses of the Zodiac," and other compartments of the sky, may comport with the degrading arts of the astrologer, but they are not only incompetent to the purposes, but completely repugnant to the noble elevation of modern astronomical science. How incongruous, then, is it that such representations, the wilest hallucinations of the human mind, should be blazoned in such brilliant colours upon our globes, and that a considerable portion of our astronomical treatises should be occupied in detailing their mythological history? Because a few shepherds in the plains of Babylon, or on the banks of the Nile, arranged and delineated the heavens according to the first crude conceptions which arose in their minds, are these chimerical representations to guide the astronomers of every nation, and throughout all succeeding generations? It becomes the astronomers of the present day to consider, whether they intend to transmit to the enlightened generations of the twentieth or thirtieth centuries the sublime discoveries of modern times, which have transformed the heavens into an immense assemblage of suns and worlds,—incorporated and disfigured with hydras, gorgons, flying-horses, three-headed dogs, and other "dire chimeras;" or whether they might not be as well qualified as the shepherds of Chaldea to reduce the starry groups, in the concave of the firmament, to a more natural, simple, and scientific arrangement.

4. The constellations, as presently depicted on our globes and planispheres, convey an *unnatural* and complex representation of the heavens, which tends to confuse the imagination of the juvenile student. On some celestial globes which I have inspected, the natural and hieroglyphic figures are so prominently engraved, and the colours with which they are bespattered so deep and vivid, that the stars, appeared not only as a secondary object, but were almost invisible, except on a very minute inspection. The animals were so nicely drawn, and exhibited such a glare of variegated colours, that the sphere appeared more like a young miss's plaything than a delineation of the starry heavens. It seemed as if the engraver had been afraid lest his pretty little dogs, and serpents, and scorpions, and flying-horses, and crabs, and lizards, should have been disfigured by the radiated groups of stars which spotted the pretty creatures; and therefore he threw them into the shade, in order that the artificial globe, which a late philosopher calls "a philosophic toy," might prove nothing more to the fair one, who occasionly twirled it round its axis, than a beautifully-coloured ball to fill up a niche in her parlour or bed-room. The same thing appears in many of our planispheres of the heavens, on the first opening of which one would imagine he was about to inspect the figures connected with the natural history of animals, or the fantastical representations illustrative of the system of pagan mythology. Whatever may be said of the utility of such delineations, it is evident they present a very awkward and *unnatural* representation of the beautiful and variegated scenery of a starry sky; and hence it is that a young person who wishes to acquire a general knowledge of the positions of the principal stars finds it extremely difficult to recognise them by our present maps and planispheres, on account of their being so much interwoven with extraneous objects, and, on this account, presenting appearances so very different from what they do in the heavens.

For these and many other reasons, it appears expedient that some change or modification should be adopted in the arrangement and delineation of the celestial orbs. Were any scheme of this kind attempted, it would be proper to proceed on the following principle, among others—namely, *to give names to the starry groups from objects which bear the nearest resemblance to the actual figures which appear in the heavens.* I shall not presume, at present, to determine what are the particular objects which might be selected for representing the constellations; as it would require a combination of astronomers to enter particularly into the discussion. It is evident, however, that a number of clusters might be reduced to mathematical figures and diagrams; and in so far as these were found to resemble the starry groups, they would form a *natural* representation. For there actually appear in the heaven—triangles, squares, parallelograms,

pentagons, crosses, trapeziums, perpendicular and parallel lines, and various combinations of geometrical schemes, some of which might be selected for the purpose proposed. It would be expedient that as many as possible of the old constellations should be preserved entire; such as Orion, Ursa Major, and others; and that those which behoved to be somewhat deranged should be so divided as that two or more of the new-formed constellations should exactly correspond to one of the old, and *vice versa*.

To any proposal of this kind, however, I am aware that many objections would be raised, particularly that it would introduce confusion into the science of astronomy, especially when references are made to ancient catalogues and observations. It is well known however that a similar difficulty has been overcome in reference to the science of *chemistry*. The new nomenclature, which was intended to express the *nature* of the substance by the *name* which is attached to it, though at first scouted by many eminent chemists and philosophers, is now universally adopted, and has introduced both simplicity and precision into the science. The same may be said of the departments of geology, botany, zoology, mineralogy, and meteorology. The principle now proposed in reference to the constellations is materially the same as that which led to the adoption of a new chemical nomenclature; and, with regard to the inconveniences attending a new set of terms, it may be observed, in the words of M. Bergman, that "those who are already possessed of knowledge cannot be deprived of it by new terms; and those who have their knowledge to acquire will be enabled, by an improvement in the language of the science, to acquire it sooner."

The opposition, however, which is generally made to every innovation, whether in science or religion, the high respect in which every thing is held which has the sanction of antiquity, the difficulty of forming such an arrangement as would combine simplicity with accuracy, and meet the approbation of astronomers, will probably postpone the attempt to some distant period. I would therefore propose, in the mean time, as matters now stand, one or other of the following plans for adoption:—1. That the stars be depicted on celestial globes and planispheres in their true positions, and apparent magnitudes, without being connected with any hieroglyphic delineations; the different constellations still retaining their former names. By this plan, the different clusters, not being encumbered and buried, as it were, in a medley of grotesque and extraneous representations, would appear in their natural simplicity, without distortion and confusion, so that the globe, being rectified to any particular position of the heavens, would appear a *natural* as well as accurate representation of the corresponding orbs of the firmament. To distinguish the boundaries of the constellations, a dotted line might be drawn around them, and each of them receive a very slight tint of colouring, so that their shape and limits may be distinguished at a glance. Or, 2. Instead of engraving the stars on a white ground, as is always done on the globes, let them be engraved on a black or a dark-blue ground, so that the several stars may appear as so many white specks, varying in size according to their apparent magnitudes, with a white border (which might be coloured if deemed expedient) around each constellation, to mark its boundaries. On this plan the principal stars in the constellation *Orion*, with its boundary, would appear nearly as represented in the following cut.

Fig. 4.

*North.*

East. West.

This mode of delineation would exhibit the most *natural* representation which can be made, on a convex surface, of the appearance of the starry sky. I am fully persuaded that globes, with either of these modes of delineation, particularly the last, would be prized by a numerous class of individuals; as I have seldom conversed with any person on this subject who would not have preferred such a simple and natural delineation to those which are bespattered with the mythological figures. Should it, however, be deemed necessary, in cases of particular and minute reference, to have globes and planispheres on the common plan, a number of delineations of both kinds

might be engraved to suit the taste of different individuals; and those to whom money is no great object would furnish themselves with one of each description, so that the one globe would prove a mutual assistance to the other.*

That the opinions I have now expressed on this subject are not altogether singular will appear from the following extract from Sir J. Herschel's "Astronomy." "Of course we do not here speak of those uncouth figures and outlines of men and monsters which are usually scribbled over celestial globes and maps, in a rude and barbarous way, to enable us to talk of groups of stars, or districts in the heavens, by names which, though absurd or puerile in their origin, it would be difficult to dislodge them. In so far as they have really any slight resemblance to the figures called up in imagination by a view of the more splendid 'constellations,' they have a certain convenience; but as they are otherwise entirely arbitrary, and correspond to no *natural* subdivisions or groupings of the stars, astronomers treat them lightly, or altogether disregard them, except for briefly naming particular stars, as α Leonis, β Scorpio, &c., by letters of the Greek alphabet attached to them." And again,—"This disregard is neither supercilious nor causeless. The constellations seem to have been almost purposely named and delineated to cause as much confusion and inconvenience as possible. Innumerable snakes twine through long and contorted areas of the heavens, where no memory can follow them; bears, lions, and fishes, large and small, northern and southern, confuse all nomenclature, &c. A better system of constellations might have been a material help as an artificial memory."†

## CHAPTER IV.

### *On the Distances of the Stars.*

To measure the length and breadth of an extensive kingdom, and to compute its dimensions, or to determine the distances between two large islands or continents, was formerly reckoned an achievement of considerable magnitude; but to measure the whole earth, to compute its area, and to determine its exact figure and magnitude, were considered as the most astonishing enterprises ever attempted by man, and almost beyond the reach of the powers with which he is endowed. Confined to a small spot in the world in which he dwells, having no scale of measurement, in the first instance, but his own dimensions, or the length of a rod or chain formed from these dimensions, how can he measure spaces hundreds of times greater than the extent of his whole visible horizon? how can he compute the distance and dimensions of places which he has never visited, and some of which he never can visit, and embrace the whole amplitude of a world which has never been thoroughly explored? The height of his body is but a fathom, and the length of his chain but a score of fathoms, and such measures dwindle into mere points when compared with the dimensions of the earth. Hence it happened that many ages elapsed before the figure and dimensions of the world in which we dwell were nearly ascertained. The powers of the human mind, however, when called into action and properly exercised, are not only capable of such enterprises, but adequate to the performance of still more elevated achievements. When the mind of man is determined on the pursuit of knowledge, and bent upon improvement, difficulties, however great, only serve as incitements to action and perseverance, and to stimulate his energies to their highest pitch of exertion. He multiplies small measures till he arrive at greater; he combines units into tens, tens into hundreds, hundreds into thousands, and thousands into millions. He combines lines into angles, angles into triangles; compares triangles, squares, and circles together; ascertains their

* The above remarks are abridged from two papers on this subject, which the author communicated twenty years ago to the London "Monthly Magazine" for October, 1818, and January, 1819, Vol. 46, pp. 201, and 500.

† Since the above was written in April, 1838, I am happy to learn that the "British Association for the advancement of Science" has had its attention directed to this subject. At the meeting at New Castle in August, 1838, it was resolved, "That it is desirable that a revision of the nomenclature of the stars should be made, with a view to ascertain, whether or not a more correct distribution of them among the present constellations, or such other constellations as it may be considered desirable to adopt, may be formed." At the meeting at Birmingham, August, 1839, the committee appointed to report on this subject stated, "That some progress has been made in reforming the nomenclature of the northern constellations; and that the stars in the southern have been commenced laying down on a plantsphere, according to their observed actual magnitudes, for the purpose of grouping them in a more convenient and advantageous manner." It is hoped, therefore, that we shall soon be presented with an arrangement and nomenclature of the starry groups, accordant with the sublime conceptions and discoveries of modern astronomy, and which shall present, on our globes and planispheres, a more perspicuous and natural representation of the heavens.

peculiar properties and relations; and, from the conclusions he deduces, constructs instruments and ascertains principles which enable him not only to measure the dimensions of this lower world, but the magnitudes and distances of the globes which roll around him in the heavens.

There is no saying at what point the human faculties will stop when once they are aroused to active operation, and stimulated to exert all their energies. We have not only ascertained the bulk of the terraqueous globe, its spheroidal figure, its diurnal and annual motions, and the relation in which it stands to other bodies in the universe, but we have determined the dimensions of the solar system, and the distances and magnitudes of most of the bodies it contains, so that we can now speak with as much certainty of the distance of the sun, or of Jupiter and Saturn, as we can do of the distance of London from Paris, or of the distances of any two places on the surface of the earth. This is an achievement which at first view might have appeared beyond the power of human genius to accomplish; but by the unwearied observations of modern astronomers, and the application of mathematical principles to such observations, they have been enabled to trace the exact movements of the machinery which is in operation around us, and to determine with precision the relative distance and position of every planet within the system of the sun. There are limits, however, beyond which it is difficult for the human faculties to penetrate. The planetary system comprises an area so vast that imagination is almost lost in the conception. A circle drawn around its circumference would measure more than eleven thousand millions of miles; and a body moving at the rate of thirty miles an hour would require above forty-two thousand years to complete the circuit; still these vast dimensions are within the limits of measurable distance. But when we attempt to pass beyond the boundaries of this system into the illimitable spaces which lie beyond, all our usual modes of computation begin to fail, and the mind is overpowered and bewildered amidst boundless space, and the multiplicity of orbs which fill the regions of immensity. We can tell that some of the nearest of these orbs are not within a certain distance, but how far they may lie beyond it the most expert astronomer has never yet been able to compute.

The principal mode by which the distance of the fixed stars has been attempted to be determined is by endeavouring to ascertain whether any of them have an *annual parallax*. I have already explained the mode by which the distances of the sun, moon, and planets is determined by means of the *horizontal parallax*, or the angle under which the earth's semi-diameter is seen at any of these bodies.* But such a mode is altogether inapplicable to the fixed stars, whose distance from the earth is so great that the horizontal parallax is quite imperceptible. Astronomers have therefore attempted to find a parallax by using the whole diameter of the earth's annual orbit as a *base line*,—namely, one hundred and ninety millions of miles,—and endeavouring to ascertain whether any of the fixed stars appear to shift their position when viewed from the opposite extremities of this line. The nature and mode of this investigation will appear from the following explanations:

The axis of the earth extended, being carried parallel to itself during its annual revolution round the sun, describes a circle in the sphere of the fixed stars equal to the orbit of the earth. Thus, (fig. 5.) let $A$ $B$ $C$ $D$ be the orbit of the earth, $S$ the sun, the dotted lines the axis of the earth extended; this axis, when the earth is at $A$, points at $a$ in the sphere of the heavens; when the earth is at $B$, it points at $b$; when at $C$, it points at $c$; and when at $D$, it points at $d$; so that in the course of a year it describes the circle $a$ $b$ $c$ $d$ in the sphere of the heavens, equal to the circle $A$ $B$ $C$ $D$. But although the orbit of the earth, and consequently the circle $a$ $b$ $c$ $d$, be immensely large, no less than many millions of miles in diameter, yet it is but a point in comparison of the boundless sphere of the heavens. The angle under which it appears to an inhabitant of the earth is insensible by any instruments or observations that have hitherto been made, and therefore the celestial poles appear in the same points of the heavens during the whole of the earth's annual course. The star $H$ is nearer the point $a$ than it is to the point $c$ by the whole length of the line $a$ $c$, yet if this line $a$ $c$, great as it is when viewed from the earth, should occupy no *sensible* space in the sphere of the heavens, the star will appear at the same distance from the pole throughout every portion of the annual revolution, and consequently will have no parallax,—which is found to be the fact.

If the annual parallax of a fixed star were sensible, the star would appear to change its place so as to describe a small ellipsis in the sphere of the heavens in the course of a year, or an annual revolution of the earth. Thus, let $G$ $E$ $F$ $I$ (fig. 6) be the orbit of the earth, and $K$ the star to be observed,—if we imagine a straight line to be drawn from the earth at $G$ through the star to a point in the heavens, as at $i$, that visual line $G$ $i$ being carried along with the earth in its annual

* "Celestial Scenery," pp. 141. 142.

motion, will describe the ellipse $h\ n\ i$; in other words, the motion of the earth round its orbit $G\ E\ F\ I$ will make the star appear

Fig. 5.

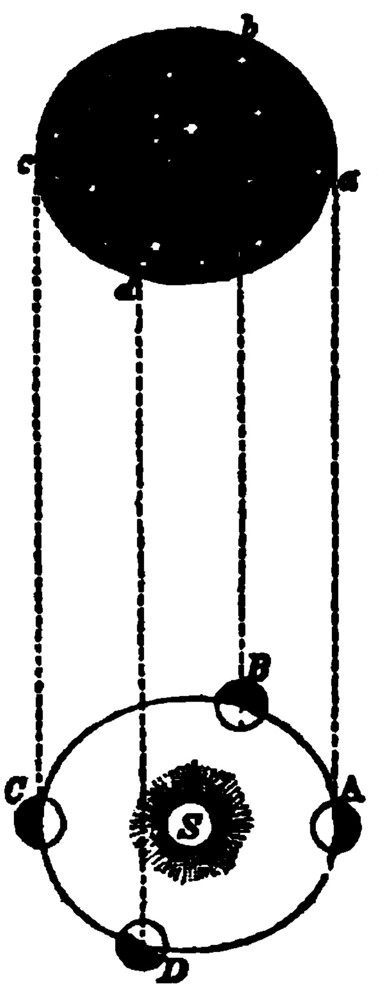
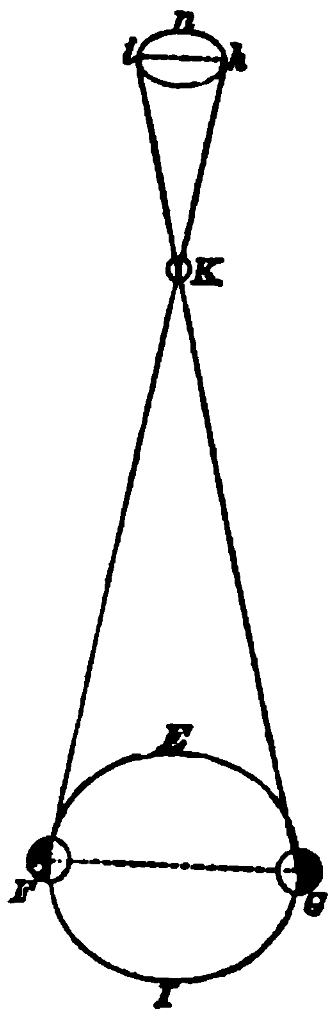



Fig. 6.




to go round the ellipse $h\ n\ i$. If the star $K$ were in the pole of the ecliptic, the ellipse it described would have the same eccentricity as the orbit of the earth, and consequently would differ very little from a circle; if it were at any distance from the pole of the ecliptic,* the greater that distance, the more oblong would be the ellipse. If the star were in the plane of the ecliptic, the ellipse would become a straight line, as $i\ h$, in which the star would appear to move one-half of the year according to the order of the signs, and contrary to the order of the signs during the other half,—somewhat similar to the appearance which the moons of Jupiter present when moving between the opposite points of their orbits. If therefore the stars were at a moderate distance from the earth, so that the diameter of the earth's orbit, $G\ F$, bore a sensible proportion to that distance, the star would be found at one time of the year, suppose the month of December, at the point $i$, and at the opposite season, in the month of June, at the point $h$; and if the angle $i\ K\ h$, which is equal to the angle $G\ K\ F$ could be found, it would constitute what is termed the *annual parallax;* and having obtained this parallax, and knowing the extent of the base line $G\ F$, or the diameter of the earth's orbit, the distance of the stars whose parallax was ascertained could then be determined by an easy process in trigonometry; for as radius : is to the sine of the angle $i\ K\ h = GKF$ : : so is the diameter of the orbit of the earth, 190,000,000 of miles : to a fourth number, which would express the distance of the particular stars from our globe.

But this angle, in respect to any of the stars, has never yet been ascertained; although astronomers for more than a century past have used the most accurate instruments which ingenuity could contrive, and the most unwearied observations in order to determine it.

Galileo appears to have been the first who thought of trying whether the annual parallax of the stars were discoverable. Taking for granted that the stars are placed at different distances from the earth, and that those stars which are nearest will appear the largest, he suggested that, by observing with a telescope two stars very near each other, one of the greatest and the other of the least magnitude, their apparent distance from each other might perhaps be found to vary as they were viewed from different parts of the earth's orbit at different times of the year; but no change of position whatever was at that period perceived.

If any change of this kind were perceptible, it behoved to be a change either in the longitude or latitude of the stars fixed upon as the subject for observation. These are found, not directly, but by first determining their declination and right ascension. The declination of a star is found by taking its meridian altitude, and subtracting the height of the equator; the right ascension is found by the time of its coming to the meridian.† We have thus two methods pointed out of attempting to determine the annual parallax of the stars: *one*, by observing if any change can be discovered in the meridian altitudes of the same star at different times of the year; the *other*, by examining whether the intervals of time between any two stars coming to the meridian

* The *pole* of the ellipse is that point in the heavens which is farthest distant from the plane of the earth's orbit, or 90° from every part of it, as the north pole of the earth is the point distant 90° from the equator. The pole of *any circle* is a point on the surface of the sphere 90° distant from every part of that circle of which it is the pole.

† The *latitude* of a star is its distance from the *ecliptic*, either north or south, counted towards the pole of the ecliptic. Its *longitude* is its distance from the first point of Aries, reckoned eastward on the *ecliptic*. The declination of a star is its distance from the *equinoctial* north or south, and the greatest declination it can have is 90°. Its *right ascension* is its distance from the first point of Aries, reckoned on the *equinoctial* eastward round the sphere of the heavens, or that degree of the equinoctial which comes to the meridian with the star. By the right ascension and declination the situation of stars in the heavens is determined, as that of places on the earth by longitude and latitude.

are equal throughout the year. If there be any sensible change of declination in any of the stars, it must be greatest in those which are near the poles of the ecliptic; but the change of right ascension must be greatest in stars in the solstitial colure, and nearest the pole of the equinoctial.

The following is the plan by which the discovery of the annual parallax, by the *change of the declination* of the stars, may be attempted. Let a telescope be placed perpendicular to the horizon, and through this instrument, when accurately adjusted, observe some star in or near the solstitial colure,* which passes through the zenith, or very near it. If the parallax of the star be sensible, there will appear a difference in its altitudes at different periods of the year, and its altitudes at the two solstices† will differ most from each other. In the month of *June* a star that passes through the zenith of any place, in north latitude, will in *December* pass *south* of the zenith, and a star that in December passes through the zenith will in June pass to the north of it, if there be any sensible parallax.

The celebrated Dr. Robert Hook was among the first who suggested this method of attempting to find the parallax of the stars. In the year 1669 he endeavoured to put it in practice at Gresham College, with a telescope thirty-six feet in length. His observation was made on the 6th of July, on the bright star in the head of *Draco* marked *Gamma*. On that day it passed 2′ 12″ north of the zenith. On July 9th it passed at the same distance as before. On the 6th of August the star passed north of the zenith 2′ 6″, and on the 21st of October it passed 1′ 48″ north of the zenith. But at that period astronomical instruments were not constructed with such accuracy as to enable the observer to determine with precision the quantity of so small angles; and even Dr. Hook himself could place no great reliance on such observations. In the year 1689, Flamstead, the astronomer royal, commenced similar observations with an instrument adapted to a refracting telescope seven feet long, and, after numerous observations, he supposed that he found the pole star nearer the pole in December than in the months of April, May, July, August, or September; and that its apparent distance from the pole was greater in April than in September, and greater in July and May than in April; and from the whole of his observations he deduced that its apparent distance from the pole in June must be forty-six seconds different from that in December. But even Flamstead himself speaks of these observations with a great deal of diffidence, owing to his doubts about the regular divisions of his instruments.

From these observations of Hook and Flamstead, supposing them to be nearly correct, Mr. Whiston computed that the greatest annual parallax of a star in the pole of the ecliptic is forty-seven seconds; and hence he calculated the distance of such stars to be about 9000 *semidiameters* of the earth's orbit, then estimated at eighty millions of miles, or about 700,000,000,000, that is seven hundred thousand millions of miles,—a distance so great that it would require a cannon ball, moving 500 miles an hour, more than 160,000 years to move across this immense interval. But we have reason to believe that the distance of the nearest stars from our globe is at least forty times the distance now stated; for modern astronomers would long since have determined the annual parallax had it been nearly so great as Hook and Flamstead supposed; nay, had it amounted to 2″ instead of of 47″ this grand problem, as it respects the nearest stars, would have been resolved.

The human mind, when ardently engaged in the pursuit of any object, is seldom deterred by difficulties; and astronomers in particular, notwithstanding the intricacies and difficulties connected with many of the objects of their investigation, have persevered in their observations and researches, and have not unfrequently arrived at the most important and unexpected results. In the year 1725, Mr. Molyneux, doubtful of the accuracy of the observations of Hook and Flamstead, began a series of observations, to ascertain, if possible, the true annual parallax. Assisted by Dr. Bradley, he placed a telescope of twenty-four feet long perpendicularly at his house at Kew, and began to observe the same bright star in Draco as Hook had done. From the 3d of December that year it was found that the star did not sensibly change its distance from the zenith for several days. On December 17th it passed a little more southerly, and continued gradually to pass more and more southerly at every transit over the meridian till the beginning of March, when it was found to pass twenty seconds more southerly than at the time of the first observation. About the middle of April it appeared to be returning towards the north, and at the beginning of June it passed the meridian at the same distance from the zenith as in December, when it was first observed. From that time it appeared more

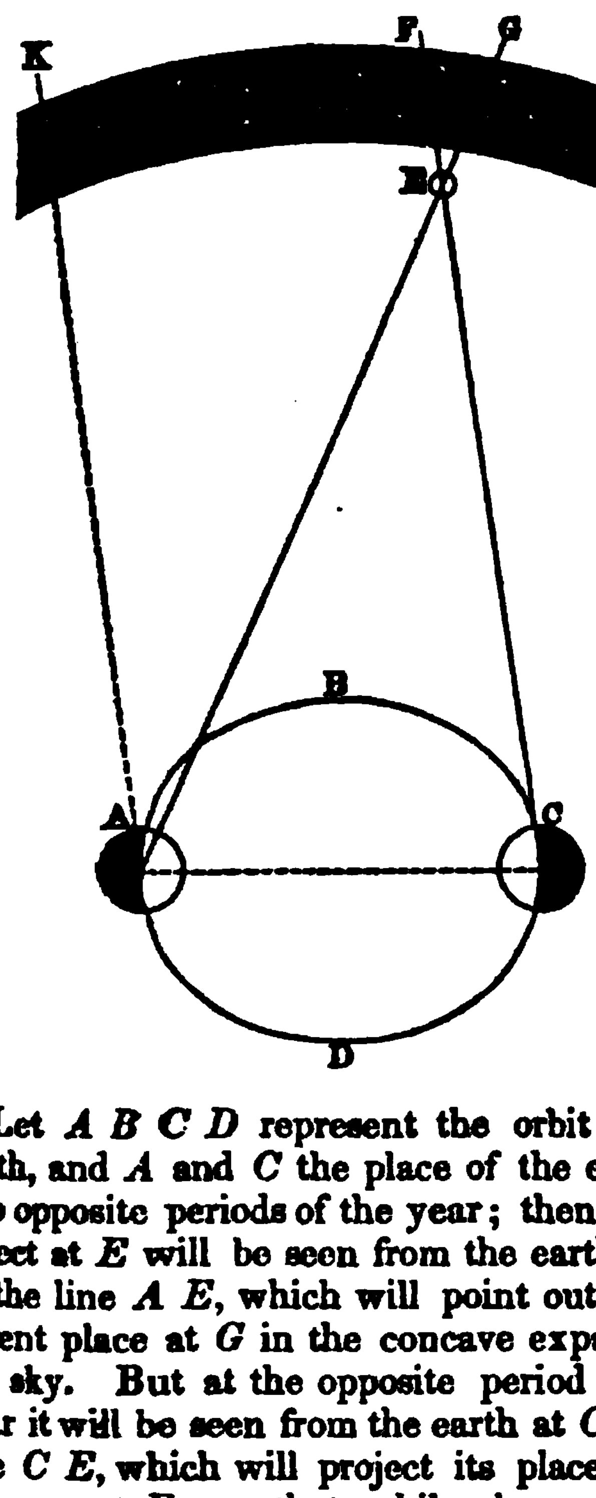
* The *colures* are two great circles passing through the poles of the world; one of them passes through the equinoctial points Aries and Libra, which is called the *equinoctial colure;* the other through the solstitial points Cancer and Capricorn, called the *solstitial colure*. They are drawn on all celestial globes and planispheres.

† The *solstitial* points, or solstices, are where the ecliptic touches the first points of Cancer and Capricorn. The summer solstice is on the 21st of June; the winter solstice is on the 21st of December.

and more northerly at every transit till September following, being then twenty seconds more northerly than in June, and no less than thirty-nine seconds more *northerly* than in March. From September the star returned towards the south till it arrived, in December, at the same situation in which it was found a twelvemonth before.

The result of these observations, so different from what was expected, was a matter of great surprise to the observers; for it appeared that the star was thirty-nine seconds more northerly in September than in March, *just the contrary to what it ought to appear by the annual parallax of the stars.* This may be illustrated by the following figure:

**Fig. 7.**




Let *A B C D* represent the orbit of the earth, and *A* and *C* the place of the earth at two opposite periods of the year; then a fixed object at *E* will be seen from the earth at *A*, in the line *A E*, which will point out its apparent place at *G* in the concave expanse of the sky. But at the opposite period of the year it will be seen from the earth at *C* in the line *C E*, which will project its place in the heavens at *F*; so that while the earth has passed from *A* to *C* the object will appear to have moved from *G* to *F*, through the space *G F*, provided there be any sensible parallax. Now, in the case of the observations stated above, the observers who in *September* saw the star at *F*, did in *March* following observe it at *K*, in the right line *A K*, parallel to *C F*, and not at *G*, where it ought to have appeared by the parallactic motion; so that, instead of finding a parallax, they found a result directly opposite to what they expected, which exceedingly perplexed the observers, and one of them, Mr. Molyneux, died before the true cause of it was discovered.

Some time afterwards Dr. Bradley repeated the same observations with an instrument of great accuracy, to which was appended a telescope twelve and a half feet long. With this instrument, which was so nicely adjusted that he could depend upon it even to half a second, he continued his observations for more than two years, not only on the bright star in Draco, above alluded to, but on many other stars, and always observed the same appearances and arrived at the same results. At last, after many reflections and conjectures on the subject, he arrived at the following conclusion—namely, that the phenomenon he had observed was owing to "the progressive motion of light, and the sensible proportion which its velocity bears to the velocity of the annual motion of the earth." In other words, that *the motion of light, combined with the progressive motion of the earth in its orbit, causes the stars to be seen in a different position from what they would be if the eye were at rest.* This position, after it was explained and demonstrated, was considered as one of the most brilliant discoveries which had been brought to light during the last century. It agrees with the velocity of light which had been deduced from the eclipses of Jupiter's satellites, and it amounts to a *sensible* demonstration of the *annual* motion of the earth. The observations which led to this discovery likewise prove the immense distance of the stars from the earth; for Dr. Bradley assures us, from the accuracy with which they were conducted, that if the annual parallax had amounted to so much as *one second* he should have discovered it.

If, then, the greatest annual parallax of the nearest stars does not amount to one second, their distance must be immense. Supposing the parallax to be exactly one second, the distance of a star having this parallax will be found by the following trigonometrical proportion:—As the sine of $1''$: is to radius:: so is the semi-diameter of the earth's orbit: to a fourth number, which expresses the distance of the star. Now, a parallax of one second determines the object to be 212,000 times further from the earth than is the sun. The distance of the sun is 95,000,000 of miles, which, multiplied by 212,000, produces 20,140,000,000,000, or more than *twenty billions* of miles. This distance is absolutely certain: it follows, as a matter of course, if the annual parallax were determined to be one second. It is the *very*

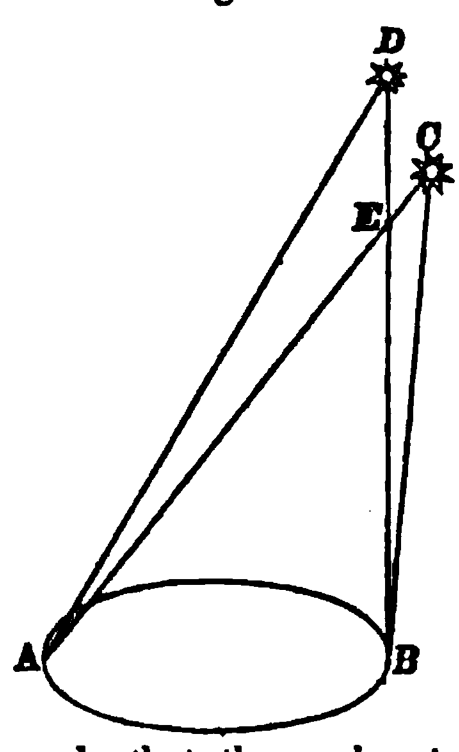
*least distance* at which any of the fixed stars can be situated from our globe; but as the parallax does not amount to this quantity, their distance must be much further than what is here stated, perhaps not less than double or treble that distance. We may acquire some faint idea of the immense distance stated above by considering that a cannon ball, flying with uniform velocity 500 miles every hour, would require *four millions, and five hundred and ninety-five thousand years* before it could reach an object at the distance we have stated. Such are the ample and inconceivable dimensions of the spaces of the universe.

Several other methods have been resorted to by astronomers in order, if possible, to determine the distance of the stars, but most of them are founded upon assumptions which have not yet been proved. The celebrated Huygens, as recorded in his "Cosmotheoros," despairing of being able to find an annual parallax, resorted to the following method:—supposing that the star *Sirius*, one of the brightest fixed stars in the heavens, to be equal in lustre and magnitude to the sun, he endeavoured to diminish the apparent diameter of the sun to the eye, so that it should appear no larger or brighter than Sirius appears to a common observer. For this purpose he closed one end of a twelve feet tube with a very thin plate, in the middle of which he made so small a hole that a very minute glass globule being put into it, so very small did the sun appear to the eye placed at the other end of the tube, that the light transmitted to the eye seemed not more splendid than that which we behold transmitted from Sirius with the naked eye. Having calculated, on the principles of optics, the quantity of diminution of the sun's apparent diameter, he found it to be only the $\frac{1}{27664}$th part; or, the light and diameter of the sun appeared 27,664 times smaller than what we daily see. Hence he concluded that were the sun at 27,664 times his present distance from us, he would appear as small as Sirius; and consequently, if Sirius be of the same magnitude as the sun, the distance of that star must be 27,664 times greater than the distance of the sun from the earth, or 2,628,080,000,000,—that is, two billions, six hundred and twenty-eight thousand and eighty millions of miles. This method of determining the distance of the stars depends upon two assumptions:—1st, that the sun and Sirius are equal in magnitude; and 2d, that the eye judged correctly of the equality of the small intercepted portion of the sun to Sirius; both of which must be considered as uncertain. But it corroborates the general position of the very great distance of the stars.

On a principle somewhat similiar, but by experiments conducted with far greater accuracy, Dr. Wollaston endeavoured to determine the same problem in relation to the stars. "This gentleman," Sir. J. Herschel remarks, "by direct photometrical experiments, open, as it would seem, to no objections, has ascertained the light of Sirius, as received by us, to be to that of the sun as 1 to 20,000,000,000. The sun, therefore, in order that it should appear to us no brighter than Sirius, would require to be removed 141,400 times its actual distance. We have seen, however that the distance of Sirius cannot be so small as 200,000 times that of the sun. Hence it follows that, upon the lowest possible computation, the light really thrown out by Sirius cannot be so little as *double* that emitted by the sun; or that Sirius must, in point of intrinsic splendour, be equal to *two suns*, and is, in all probability, vastly greater."

The late Sir William Herschel proposed another method of determining the annual parallax by means of *double stars*, which he supposed would be free from the errors of other methods, and of such a nature that the parallax, even if it should not exceed the tenth part of a second, may still become visible. The following figure and description will convey a general idea of this method:

Fig. 8.




Let *A* and *B* (fig. 8) represent the earth at two opposite points in its orbit, and *C* and *D* two stars of different magnitudes. Then, if when the earth is at *B*, the two stars appear to us near each other, as at *C* and *E*, it was thought that when the earth arrived at *A* the two stars might appear further apart, as at *C* and *D*; in other words, that the angles at which they would appear to us in the two cases would be different, the angle *D A C* being larger than the angle *D B C*, in which case the angle of parallax might be computed. But it does not appear that any difference in the angles referred to has yet been found, or that any definite conclusions respecting parallax have hitherto been deduced from this method, excepting the general position that the stars are at too great a distance to be subjected to our calculations, or that our angular instruments are still in too imperfect a state to detect so small an angle as that of the annual parallax.

While writing the above, (December, 1838,) I perceived an announcement in certain literary journals, that Professor Bessel, of Konigsberg, had addressed a letter to Sir John Herschel, which was immediately communicated to the Royal Astronomical Society, containing an account of the discovery of the annual parallax and the observations on which it was founded. In the introduction to this communication Professor Bessel says—"After so many unsuccessful attempts to determine the parallax of a fixed star, I thought it worth while to try what might be accomplished by means of the accuracy which my great Fraunhofer heliometer gives to the observations. I undertook to make this investigation upon the star 61 *Cygni*, which, by reason of its great proper motion, is perhaps the best of all, which affords the advantage of being a double star, and on that account may be observed with greater accuracy, and which is so near the pole that, with the exception of a small part of the year, it can always be observed at night at a sufficient distance from the horizon." The professor began his observations in September, 1834, but various circumstances prevented them from being regularly continued at that period. They were resumed in 1837 with certain hopes of success. He selected among the small stars which surrounded the double star 61 *Cygni* two stars between the ninth and tenth magnitudes, of which one ($a$) is nearly perpendicular to the line of direction of the double star, the other ($b$) nearly in this direction. He measured with the heliometer the distances of these stars from the point which bisects the distance between the two stars 61 Cygni, and generally repeated the observations sixteen times every night, and when the atmosphere was unusually steady he made more numerous repetitions. The places of both stars, referred to the middle point of the double star, he calculated, for the beginning of 1838, to be—

| | Distance. | Angle of Position. |
|---|---|---|
| $a$ | 461″.617 | 201° 29′ 24″ |
| $b$ | 706″.279 | 109° 22′ 10″ |

In these observations, he concentrated his attention as far as he could on the *distance* of the small stars from the double star, as being the most important point to be ascertained. His communication contains tables of all his measures of distance, freed from the effects of refraction and aberration, and reduced to the beginning of 1838.

It would be uninteresting to the general reader to enter into all the details of observations, corrections, and calculations which Professor Bessel's communication contains, as they can only be understood by practical astronomers. I shall therefore only state his general conclusion, which seems to be legitimately deduced from his observations and reasonings, and may be considered at least as a very near approximation to the point, if not perfectly correct. The result then is, that the annual parallax of the star 61 *Cygni* is 0″.3136; that is, somewhat less than *one-third of a second*. It follows that the distance of this star from the sun is 657,700 times the mean distance of the earth from the sun; and as the distance of the sun from the earth is 95,000,000 of miles, this number multiplied by the former produces 62,481, 500,000,000, or *sixty-two* BILLIONS, *four hundred and eighty-one thousand five hundred* MILLIONS of miles, which is the distance of the star 61 *Cygni* from the sun, and which of course is nearly about the same distance from the earth; the earth being in one part of its course ninety-five millions of miles nearer the star than this distance, and in the opposite part of it ninety-five millions of miles beyond it. This, I have no doubt, will be considered as one of the most interesting and splendid discoveries which have been made in astronomy for a century past. It lays a foundation for precise and definite conceptions of the distances of some of the starry orbs, of the amplitude of the celestial regions, and of the magnitude and grandeur of those countless orbs which diversify the spaces of immensity. It likewise proves to a demonstration the annual motion of the earth round the sun, and all the principles and phenomena with which it is connected, as well as corroborates the general views of former astronomers respecting the immense distance of the fixed stars.

Professor Bessel concludes his communication in these words:—"As the annual proper motion of *a Cygni* amounts to 5″.123 of a great circle, the *relative* motion of this star and the sun must be considerably more than sixteen semi-diameters of the earth's orbit, [that is, one thousand, five hundred and twenty millions of miles,] and the star must have a constant aberration of more than 52″. When we shall have succeeded in determining the elements of the motion of both the stars forming the double star, round their common centre of gravity, we shall be able to determine the sum of their masses. I have attentively considered the preceding observations of their relative positions, but I consider them as yet very inadequate to afford the elements of the orbit. I consider them as sufficient only to show that the annual angular motion is somewhere about two-thirds of a degree, and that the distance at the beginning of this century had a minimum of about 15″. We are enabled hence to conclude

that the time of a revolution is more than 540 years, and that the semi-major axis of the orbit is seen under an angle of more than 15″. If, however, we proceed from these numbers, which are merely *limits*, we find the sum of the masses of both stars less than half the sun's mass. But this point, which is deserving of attention, cannot be established till the observations shall be sufficient to determine the elements accurately. When long-continued observation of the places which the double star occupies amongst the small stars which surround it shall have led to the knowledge of its centre of gravity, we shall be enabled to determine the two masses separately; but we cannot anticipate the time of these further researches. I have here troubled you with many particulars; but I trust it is not necessary to offer any excuse for this, since a correct opinion as to whether the investigation of the parallax of 61 *Cygni* has already led to an approximate result, or must still be carried further before this can be affirmed of them, can only be formed from a knowledge of these particulars. Had I merely communicated to you the result, I could not have expected that you would attribute to it that *certainty* which, according to my own judgment, it possessed."

The distance inferred from the parallax ascertained by Bessel is more than three times greater than what was formerly considered the *least distance* of any of the fixed stars. In order to acquire some rude conceptions of this distance, it may not be inexpedient to illustrate it by the times which certain moving bodies would require to move along such a space. *Light* is the swiftest moving body with which we are acquainted; it flies from the sun to the earth, a distance of ninety-five millions of miles, in about eight minutes, or at the rate of 192,000 miles every moment of time; yet light, incomprehensively swift as its motion is, would require ten years and 114 days to fly across this mighty interval; so that if the star 61 *Cygni* were supposed to be only just now launched into existence, it would be more than ten years before its light could reach the distant globe on which we dwell, so as to appear like a small star twinkling in our sky. Suppose a cannon ball to move 500 miles every hour without intermission, it would require fourteen millions, two hundred and fifty-five thousand, four hundred and eighteen years before it could move across the same interval. But to come to motions with which we are more familiar: suppose a steam carriage to set out from the earth with a velocity of twenty miles an hour, or 480 miles a day; at this rate of motion, continued without intermission, it would require 356,385,466, or three hundred and fifty-six millions, three hundred and eighty-five thousand, four hundred and sixty-six years before it could pass from our globe to the star alluded to above—a number of years sixty-one thousand times greater than the whole period which has elapsed since the Mosaic creation.

Such distances are amazing, and almost terrifying to the human imagination. The mind is bewildered, confounded, and almost overwhelmed, when attempting to form a conception of such portions of immensity, and feels its own littleness, the limited nature of its powers, and its utter incapacity for grasping the amplitudes of creation; but although it were possible for us to wing our flight to such a distant orb as that to which we have referred, we should still find ourselves standing only on the extreme verge of the starry firmament, where ten thousands of other orbs, a thousand times more distant, would meet our view. We have reason to believe that a space nearly equal to that which we are now considering intervenes between most of the stars which diversify our nocturnal sky. The stars appear of different magnitudes; but we have the strongest reason to conclude that in the majority of instances this is owing, not to the difference of their real magnitudes, but to the different distances at which they are placed from our globe. If, then, the distance of a star of the first or second magnitude, or those which are nearest us, be so immensely great, what must be the distance of stars of the sixteenth or twentieth magnitudes, which can be distinguished only by the most powerful telescopes? Some of these must be several thousands of times more distant than the star 61 Cygni, whose distance now appears to be determined. And what shall we think of the distance of those which lie beyond the reach of the most powerful telescopes that have yet been constructed, stretching beyond the utmost limits of mortal vision, within the unexplored regions of immensity? Here even the most vigorous imagination drops its wing, and feels itself utterly unable to penetrate this mysterious and boundless unknown.

The vastness of the spaces and greatness of the distances to which we have adverted ought not, however, to prevent any one from acquiescing in the statements we have now made; for space is boundless,—absolutely infinite. A seraph might wing its flight with the swiftness of light for millions of years through the regions of immensity, and never arrive at a boundary where it might be said, "Hitherto mayest thou approach, but no farther;" and we have reason to believe, from what we already know of the Creator and his works, that during the whole course of such an excursion, new objects and new scenes of

glory and magnificence would be continually rising to his view. To suppose otherwise would be to set boundaries to space, and to prescribe limits to the infinite perfections of the Divinity. That incomprehensible Being who formed the universe fills immensity with his presence; his power and wisdom, and all his other perfections, are *infinite;* and therefore we should expect that the plans on which he has constructed the systems of the universe should be like himself, vast, boundless, and inconceivable by mortals. Were we to find the plans of the universe circumscribed like those which were represented by the ancient astronomers,—who imagined the firmament a solid sphere with a number of tapers whirled round the earth,—we should be apt to think that the Creator of the world was a limited being; but when we contemplate the vast amplitude of planetary systems, and the immense spaces by which they are separated from each other, we behold plans and operations which are in perfect unison with the immensity of his nature, with his boundless power, his uncontrollable agency, and his universal presence. Wherever we turn our eyes throughout the scene of nature, and fix our attention on its plans and movements, we uniformly find the Creator *acting like Himself;* and in no case is this more strikingly displayed than in the grandeur and magnificence of the orbs of heaven, and *the immense spaces with which they are surrounded.*

This is likewise the representation which the Scriptures give us of the immensity and incomprehensible nature of the Deity. "Great is Jehovah and of great power; his understanding is infinite; his greatness is unsearchable." He is not only "high above all nations," but "his glory is *above the heavens.*" "He dwelleth on high, and humbleth himself to behold the things" not only that are "on the earth,". but even "the things that are in the heavens." Vast as the celestial spaces are, "he meted out heaven with the span," and "stretched forth the heavens alone." "Among the gods there is none like unto thee, neither are there any works like unto thy works." "Canst thou by searching find out God? Canst thou find out the Almighty to perfection? Who can utter the mighty operations of Jehovah? Who can show forth all his praise? Lo, these are but parts of his ways, but the thunder of his power, or the full extent of his omnipotence, who can comprehend?" In relation to a Being who is thus described, we can expect nothing but what is wonderful and incomprehensible by finite minds. The declarations of inspired men bear testimony to the discoveries of astronomy as in perfect unison with the attributes of the Divinity, so that science and revelation completely harmonize in the views they unfold of the plans and arrangements of the Deity, and of the immense spaces which intervene among the systems of the universe.

Whether man will ever be permitted to traverse any of the vast spaces of the universe, to which we have now adverted, is a question which is at present beyond our province to resolve. In our present state of corporeal organization it is impossible to wing our flight even to the nearest celestial orb in that system of which we form a part, much less to the distant starry regions. How pure spirits, disconnected with material vehicles, may transport themselves from one region of creation to another, it is impossible for us, in the present state, to form a conception. But it is possible to conceive of a system of organization far more refined than the present, and susceptible of a power of motion far surpassing what we have an opportunity of witnessing in this terrestrial sphere—a locomotive power which might enable an intelligent agent to keep pace with the rapid motions of the celestial orbs. We have only to suppose organical vehicles constructed with matter far more subtile and refined than hydrogen gas, or the ethereal fluid, and approximating to the tenacity of light itself. As we find animalculæ many thousands of times less than the least visible point, their bodies must be constructed of materials extremely subtile and refined; and hence we may infer that the same Allwise Intelligence who formed such minute and refined structures can with equal ease construct a material organization for the residence of a rational soul out of the finest materials which creation can supply, and endow it with a capacity of rapid motion superior to that of some of the celestial globes which roll around us. It is not improbable that angelic beings are connected with such a system of material organization, which enables them to move with rapidity from one part of creation to another; and it is possible that man, in a future world, may be invested with such vehicles and such powers of rapid motion. At the same time, even with such locomotive powers, only a small portion of the universe could be supposed to be visited or explored, even after a lapse of ages. It is highly probable that, at this moment, there is not a single subordinate intelligence, even of the highest order of created beings, who is acquainted with every region of universal nature and the objects it contains, and that the greater part of the vast universe, with its scenery, movements, and inhabitants, is known only by Him who formed it by his power and fills it with his presence.

## CHAPTER V.

### *On the Magnitude of the Stars.*

In our attempts to ascertain the *magnitudes* of any of the heavenly bodies, we must first endeavour to determine the distances at which they are placed from our abode; and in the next place we must measure, as accurately as possible, the *apparent diameters* of the bodies whose magnitudes we wish to determine. The extreme difficulty of determining these two points, in certain instances, on account of the smallness of the angles which require to be measured, has hitherto prevented us from ascertaining with precision the real magnitudes of the bodies connected with the sidereal heavens. We formerly were led to conclude on good grounds, that their distances were almost immeasurably great, and consequently that, as they emit a certain degree of splendour to our eye, even from such remote distances, their *bulk* must be immensely great. But no precise conceptions could be formed as to this point so long as the annual parallax of some of the stars remained undetermined.

The annual parallax of the star 61 *Cygni* being now in all probability ascertained, (as stated in the preceding chapter,) we are in possession of certain *data* which may lead to the determination of the *real magnitude* of that body. But a difficulty still remains. The stars are found to have no sensible diameters. When viewed through telescopes of the greatest power, they present no visible disks, or well-defined surfaces to the eye, as the planets do, when viewed through such instruments, but appear only as so many shining and undefined points. When they are viewed through a telescope of moderate size, their diameters appear less than when examined by the naked eye, but considerably more brilliant. When we view them with a telescope of greater power, the apparent diameters will be somewhat increased, but not according to any regular proportion, as happens in the case of the planets; and even when seen with the same power, through different telescopes, their apparent magnitudes are not precisely the same. Sir William Herschel, who viewed these bodies under almost every aspect, uniformly found that their diameter was less in proportion as the higher powers were applied; and the smallest proportional diameter he ever obtained was when he employed the extraordinary power of 6450 times. From such observations it appears that the apparent diameters of the fixed stars do not arise from any sensible disk, but from other causes with which we are not acquainted. Dr. Halley remarks that "the diameters of Spica Virginis and Aldebaran (two stars of the first magnitude) are so small, that when they happen to immerge behind the dark edge of the moon, they are so far from losing their light gradually, as they must do if they were of any sensible magnitude, that they vanish at once with all their lustre, and emerge likewise in a moment, not small at first, but at once appear with their full light, even although the emersion happen when very near the cusp, where, if they were four seconds in diameter, they would be many seconds of time in getting entirely separated from the limb. But the contrary appears to all those who have observed the occultations of those bright stars." Every one who has been in the habit of viewing the starry firmament with good telescopes will at once admit that, although that instrument brings to view numerous stars which the unassisted sight cannot perceive, yet they appear only as luminous points with no well-defined sensible diameters, although their light is much more brilliant than to the naked eye.

Hence the difficulty of determining, with precision, the real magnitudes of any of the fixed stars. From their immense distance we are perfectly certain that they are bodies of immense size, otherwise they would be altogether invisible from our terrestrial sphere, or from any part of the solar system. But we have hitherto obtained no sufficient data for estimating their exact size, as we have done in relation to the globes which compose the planetary system. Since, then, the apparent diameters of the stars, even those of the *first* magnitude, are so small as not to amount to a single second, we cannot hope, in the mean time, to determine their measure with any degree of certainty. We may assign them a measure which we certainly know they do not exceed, but we cannot be sure that that measure is not too great. All luminous objects appear larger than those of the same dimensions which are opaque. The planet Mercury, when in its greatest brightness, appears larger than when it is seen to pass, like a dark spot, across the disk of the sun, although it is nearest the earth in this last position. The

apparent diameters of the fixed stars are much smaller than they have generally been supposed by those who have attempted to measure them. Yet small as they are, their real magnitude must be *very great*, since they are visible to our sight at the immense distance at which they are placed. In proportion to the greatness of their distance, and the smallness of their apparent diameters, will be their real magnitudes. If we suppose the apparent diameters of any of the stars observed by Dr. Bradley to be equal to the 400,000th part of the sun's apparent diameter, or $\frac{1}{200}$th of a second—which is a probable supposition for a star of the second magnitude,—it will follow that such a star is equal to the sun in magnitude. For, if the sun were removed to the distance at which such a star is situated, he would appear no larger than those twinkling points, nay, would perhaps disappear altogether from our view. From all the observations and reasonings that have been entered into on this subject, we have no proofs that any of the stars are less than the sun, but it is more probable that many of them equal and even far surpass that luminary in their real dimensions and splendour. Having obtained the parallax of 61 *Cygni*,* if we could find the exact apparent diameter of that star, its real bulk could be calculated with as much ease and certainty as the bulk of the sun, or moon, or any of the planets. But as this important element in the calculation is still a *desideratum*, we must resort to other methods by which we may arrive at the nearest approximation to the truth.

I have already alluded to the photometrical experiments of Dr. Wollaston, in relation to the comparative quantity of light emitted to our eye from the star Sirius and from the sun. In reference to these experiments, Sir John Herschel, in a marginal note, remarks:—"Dr. Wollaston assuming, as we think he is perfectly justified in doing, a much lower limit of *possible* parallax in Sirius than we have adopted in the text, has concluded *the intrinsic light of Sirius to be nearly that of* FOURTEEN SUNS." Sir William Herschel informs us that, with a magnifying power of 6450, and by means of his new micrometer, he found the apparent diameter of *Vega* or α Lyræ to be 0″ 355: this will give the real diameter of the star about *thirty-eight* times that of the sun, or 33,440,000 miles, supposing its parallax to be one second. Were this its true estimate its solid contents would be 19,579,357,857,382,400,000,000,† or, above nineteen thousand five hundred and seventy-nine *trillions* of miles; which is, *fifty-four thousand eight hundred and seventy-two times* larger than the solid contents of the sun. The magnitude of such a globe is altogether overpowering to the human imagination, and completely baffles every effort to approximate to a distinct conception of an object of such amazing amplitude and splendour. We have formerly shown‡ that the *sun* is a body of so vast dimensions that the human mind, in its present state, can form no adequate conceptions of it; that it is more than 500 times greater than all the planets, satellites, and comets of our system; that it is equal to thirteen hundred thousand globes as large as the earth; that its surface contains an amplitude fifty-three millions seven hundred and seventy-thousand times larger than the view from Mount Etna, which comprises an extent of 45,000 miles; and that, were a landscape on the sun of this extent to be contemplated every two hours, it would require twenty-four thousand five hundred years before the whole surface of this luminary could be in this manner surveyed. What, then, shall we think of the probable existence of a luminous globe fifty-four thousand times greater than the expansive globe of the sun!

However amazing the magnitude of such a body may appear, we ought not on this account to consider the existence of such an orb as either improbable or incredible. Prior to the first discoveries of modern astronomy two or three centuries ago, no one could have believed that the sun is a body of such an immense size as he is now found to be, or that the planetary system occupies so extensive a range as astronomers have now determined it. And we are not to conceive that even the immense amplitude of the sun is the highest scale of magnitude which the Creator has prescribed to himself in his arrangements of the universe. From the knowledge we have already acquired of the vastness of the scale on which creation is constructed, we have reason to believe that bodies exist in it far surpassing, in magnitude and grandeur, any of the globes to which we have alluded. There are certain lucid specks in the heavens which can only be perceived by the most powerful telescopes, which we are quite certain, from

* This star belongs to the constellation *Cygnus*, or the Swan. Its right ascension for January 1, 1839, was 20h 59′ 41″, and its declination 37° 57′ 42″ north. In places of 52° of N latitude, this star passes the meridian within two or three minutes of the zenith. It is a star of about the fifth magnitude. It is 28 degrees nearly due east from the bright star *Vega* or α Lyræ, in the constellation of the Harp, and nearly nine degrees south by east of *Deneb*, or α *Cygni*, the principal star in the Swan.

† In some editions of the "Improvements of Society," this number is inaccurately stated, the cube of the diameter having been by mistake subsituted for the solid contents of the body, but the general result of the comparative magnitudes of the two bodies is the same.

‡ "Celestial Scenery," chap iii. sect. 10

their immense distance, must comprise a mass of matter thousands of times larger than our sun,—either a distinct mass of materials or a congeries of shining globes so near each other that the separate bodies cannot be distinguished. As the distance between the great globes of the universe is incomprehensible by limited intellects, so the *magnitude* of some of these bodies may be so great as to surpass every estimate and every conception we may have hitherto formed on this subject. Such views of the magnitudes of creation are quite in accordance with the ideas we ought to entertain of a Being who is eternal, omnipresent, omnipotent, and incomprehensible.

But, without going beyond the strict deductions of science, we may fairly conclude that there are few stars in the concave of our sky that do not equal, and even surpass, our sun in size and in splendour; and if so, what a glorious and overwhelming scene does creation present to an intelligent and contemplative mind! Here we are presented with a scene on which the highest order of created beings may expatiate for myriads of ages, and objects, ever wonderful and ever new, may still present themselves to the astonished mind throughout the whole length of its immortality; so that the most expansive intellects shall never want subjects of sublime investigation during all the revolutions of an interminable existence.

We are not to imagine that all the stars, even those which appear with the same brilliancy, are of the same size. We have reason to believe that a *variety*, in this respect, exists among those distant orbs, as well as among the bodies which compose the planetary system, and in other departments of nature. Various considerations tend to show that "one star differeth from another star in glory," not only as they appear to the naked eye, but in *reality*, as to their intrinsic magnitude and splendour. Some of the telescopic stars appear of very different colours, one exhibiting rays of an orange or ruddy hue, another blue, another yellow, and another green, indicating a difference in their constitution and in the nature of the light they emit. Among the double stars, the one which is found revolving round the other is evidently the smaller body, as its light is not distinguishable without a high magnifying power, and yet its distance from the earth must be nearly the same as that of the larger star around which it revolves. Recent observations tend to prove that some of the smaller stars have not only a greater annual parallax than those which are most brilliant, but an absolute motion in space much greater than those of the brightest class, which indicates that there is a difference in the real size of those bodies, and that some of the stars which appear smallest to our eye may be the largest in real dimensions; but the smallest of them are, undoubtedly, bodies of such magnitudes as surpass our distinct comprehension.

Some readers, from their ignorance of the mathematical principles of astronomy, and from being incapable of appreciating the observations to which we have referred, are apt to view with a certain degree of scepticism the conclusions which astronomers have deduced respecting the distances and magnitudes of the stars. Perhaps the following consideration, level to the capacity of every man of common sense, may have a tendency to convince even the most sceptical that the stars are situated at an almost incalculable distance from the earth.

Suppose a telescope to magnify 400 times, that is, makes a distinct object appear four hundred times nearer, and four hundred times larger in diameter, than to the naked eye. With an instrument of this description I have been enabled to read a person's name, the letters of which were not above half an inch in length or breadth, at the distance of more than two miles. When this telescope is directed to the moon, it enables us to perceive the shadows of its mountains, and other minute portions of its scenery, and even to distinguish rocks and cavities less than a mile in diameter. When directed to the planet Venus, it exhibits it as a large splendid body, with either a gibbous, a half-moon, or a crescent phase. When directed to Jupiter and Saturn, it makes these orbs appear several times larger than the moon does to the naked eye, and enables us to perceive the dark belts which run across the one, and the rings which surround the other. Now, if this same instrument be directed to the fixed stars, it shows them only as so many luminous *points*, without any well-defined diameters. It brings to view hundreds and thousands of stars which the naked eye cannot discern; but although they appear somewhat more brilliant, they appear, on the whole, no larger in diameter than the stars in general do to the unassisted sight. This circumstance I consider as a palpable and *sensible* evidence of the immense distance of the fixed stars; for bodies at the distance of nine hundred, and even of eighteen hundred millions of miles, appear magnified in proportion to the power of the instrument; and why should not the fixed stars appear magnified in the same proportion, and present to the eye large disks like the planets, were it not on account of their incalculable distance? Were they only at a moderate distance from the planetary system—suppose ten times the distance of Saturn, or nine thousand millions of miles,—this would undoubtedly be the case; but observation proves

the contrary. When we view a planet—for example *Saturn*, which is distant nine hundred millions of miles—through a telescope magnifying 400 times, we contemplate it as if we had been carried to a point only the four hundredth part of its distance; that is, we view it as if we were brought within little more than *two millions* of miles of its surface. In other words, we see it of the same magnitude, and nearly with the same distinctness, as if he had surmounted the law of gravitation, and been transported more than 897 millions of miles from our present abode in the direction of that orb.

When such an instrument is directed to the fixed stars, it does not lose its power as a telescope; this is proved by its presenting the *nebulæ*, which are invisible to the naked eye, as large, well-defined spaces in the firmament. It carries us within the four hundredth part of their actual distance, and enables us to contemplate them just as we would do if we were 400 times nearer them than we are. Let us suppose, as formerly, the distance of the nearest stars to be 20,000,000,000,000, or twenty billions, of miles, we contemplate such stars by this instrument as if we were carried to a station nineteen billions nine hundred and fifty millions of miles from the place we now occupy, where we should still be fifty thousand millions of miles* distant from these bodies. Supposing the sun were removed to a point fifty thousand millions of miles from the place he now occupies—which is 526 times his present distance,—he would appear 526 times less in diameter than at present, or under an angle of little more than 3½ seconds, which is less than the apparent diameter of Uranus, a body which is generally invisible to the naked eye; so that if a star be distant twenty billions of miles, and equal to the sun in magnitude, it should appear no more than a point when viewed with a telescope magnifying 400 times. Supposing, then, that we were transported through the immense space of 19,950,000,000,000 miles, we behoved to be carried forward several thousands of millions of miles further before those distant orbs would appear to expand into large disks like the moon, or like Jupiter and Saturn, when viewed through telescopes.

The above considerations prove to a demonstration that the nearest stars are removed from us at immense and inconceivable distances; and if their distance be so great, their *magnitudes* must likewise be astonishing, otherwise they would be altogether invisible either to the naked eye or by the telescope; for a distant visible object must always be considered as having a magnitude proportional to its distance and its *apparent* diameter.

## CHAPTER VI.

### *On New Stars.*

To almost every eye but that of the astronomer, the starry firmament presents the same general aspect. To a common observer, the nocturnal heavens exhibit the appearance of a vast concave bespangled with countless numbers of shining points, of various degrees of brilliancy, and distributed over the sky apparently without any order or arrangement.—Whether the clusters of stars which are seen in summer and in winter are the same,—whether the stars which are seen in one region of the heavens at six o'clock in the evening are identically the same which are seen in the same quarter at midnight, or at three in the morning,—whether there be any stars which were seen by our forefathers which are no longer visible,—whether any stars unknown to former generations can now be traced in the firmament,—or whether any of those orbs which are visible at one time are invisible at another,—to such inquiries there is not one out of a thousand of those who have occasionally gazed at the starry heavens that could give a satisfactory reply. It is the industrious astronomer alone, who, with unwearied observations spends sleepless nights in surveying the various regions of the celestial vault, that can tell with certainty whether or not any changes occasionally take place in reference to any of the starry orbs.

The first account we have of any changes having been perceived among the stars is that recorded by Hipparchus, of Rhodes, a celebrated astronomer who flourished about 120 years before the Christian era. About this period, this accurate observer of the heavens perceived, in a certain part of the firmament, a star which he had never observed before, and of which he could find no record in the observations of his predecessors. Struck with this new and unexpected phenomenon, he began to doubt whether changes might not happen among the celestial orbs as well as in the scene of nature here below. In order that

* The following is the calculation expressed in figures:

400) 20,000,000,000,000, dist. of the star.
50,000,000,000, dist. as viewed by the telescope.
19,950,000,000,000, dist. from the earth at which we view it.

such changes when they happen might be known to future generations, he began to form a catalogue of all the stars visible in that part of the world where he resided, noting down the place and apparent magnitude of each star, till he at length completed a list of all the visible stars in the heavens; which was the first catalogue of those luminaries of which we have any account in history. It is much to be regretted that we have no specific account of the particular part of the heavens where this new star appeared, as it might have led us to determine whether it be still visible, or whether it be subject to periodical changes, or have altogether disappeared.

In the year 130 after the Christian era, another new star is said to have made its appearance. In the year 389, a new star appeared near α Aquilæ, or Altair, in the constellation of the Eagle. Its appearance was sudden; it continued three weeks, emitting a splendour equal to that of Venus, and afterwards entirely disappeared. In the ninth century, a new star appeared in the fifteenth degree of Scorpio, which is said to have emitted as much light as is reflected from one quarter of the moon. In 945, a new star appeared between the constellations of Cepheus and Cassiopeia; and another, in 1264, near the constellation Cassiopeia; but of these stars the accounts are so vague and imperfect that we can form no distinct conceptions of the phenomena they exhibited.

The most striking and wonderful phenomenon of this kind of which we have an authentic and distinct description occurred in the beginning of November, 1572, when a new star appeared in Cassiopeia, forming nearly a rhombus with the three largest stars, α, β, γ, of that constellation. Its appearance was sudden and brilliant. Its phenomena were so striking that the sight of it determined the celebrated Tycho Brahe to become an astronomer. He did not see it at half an hour past five, when he was returning from his house to his laboratory; but returning about ten, he came to a crowd of country people who were staring at something behind him. Looking round, he saw this wonderful object. It was so bright that his staff had a shadow; it was of a dazzling white, with a little of a bluish tinge. It had no tail or hair around it similar to comets, but shone with the same kind of lustre as the other fixed stars. Its brilliancy was so great as to surpass that of *Lyra* and *Sirius*. It appeared even larger than Jupiter, which was then at its nearest approach to the earth, and by some was estimated to be superior to the planet Venus in its greatest lustre. It was even seen by those who had good eyes at noonday; a circumstance which never happens in the case of any of the other stars, or even of the planets, except Venus, which has sometimes been seen in daylight in certain peculiar positions. During night, it was frequently seen through thin clouds which entirely intercepted the light of the other stars. In this state it continued to shine with undiminished brilliancy during the remaining part of November, or more than three weeks. It did not, however, continue much longer with this degree of brightness, but gradually diminished in its lustre. In the month of December, it appeared to be only equal to Jupiter; in January, 1573, it appeared a little less than that planet, but still somewhat larger than stars of the first magnitude, to which it appeared about equal during the months of February and March; thus gradually diminishing in brightness, in April and May, it was like a star of the second magnitude; in the months of June, July, and August, it was equal only to the largest stars in Cassiopeia, which are mostly of the third magnitude; in September, October, and November, it was no larger than a star of the fourth magnitude; in December, it was about equal to the star called *Gamma*, which was nearest to it; towards the end of 1573, and during the month of January, 1574, it was but little superior to stars of the fifth magnitude; in February, it was no larger than a star of the sixth magnitude; and in the month of March it entirely disappeared, having continued visible from the beginning of November, 1572, to March, 1574, a period of about sixteen months. It was remarked that as it diminished in size it was likewise subject to certain changes in colour and brightness. When it appeared largest, its light was *white* and brilliant; after which it appeared a little *yellowish*; and in the beginning of spring, 1573, it approached something to the colour of Mars, being reddish like the star *Aldebaran*, or the Bull's Eye, and a little less bright than the star in the right shoulder of *Orion*. In the month of May that year, it was of a pale livid white, like Saturn; which colour, as likewise its sparkling appearance, continued to the last, only growing more dim and faint as it approached the period of its disappearance.

Such were the appearances and changes of this wonderful star. These phenomena were particularly observed by several astronomers of that period, especially by Tycho Brahe, who wrote a treatise on the subject, in which he determined its longitude and latitude, and demonstrated that it was situated in the region of the fixed stars, at a much greater distance from the earth than the sun, moon, or any of the planets, as it had no sensible parallax, and remained in the same point of the heavens during the whole period

of its appearance. This star was likewise diligently observed by Cornelius Gamma, who says that on the night of the 8th November, 1572, he viewed with some attention that part of the heavens, in a very serene sky, but saw nothing uncommon; but that the next night, November 9th, it appeared with a splendour surpassing all the fixed stars, and scarcely less bright than Venus. The longitude of this star, as determined by Tycho, was 9° 17′, and 53° 45′ of north latitude.

The point in the heavens where this star appeared may be ascertained from the following figure, which exhibits a representation of the principal stars in Cassiopeia. The general position of this constellation may be found from the map of the circumpolar stars, Plate III. It is almost directly opposite *Ursa Major*, or the Great Bear. A line drawn from the Bear through the pole-star meets Cassiopeia at nearly an equal distance on the other side of that star. When the Bear is at its lowest position below the pole, Cassiopeia is near the zenith, and *vice versa*. In the annexed representation (fig. 9) the large star towards the left points out the place which was occupied by the new star, which, with the three stars $\alpha$, $\beta$, $\gamma$, forms a kind of rhombus, or irregular square. The one on the left above the new star is $\beta$, and is also known by the

Fig. 9.

name of *Caph*. The one to the right of Caph and a little higher is $\alpha$, distinguished likewise by the name *Schedir*. Below Schedir, and a little to the right, is the star $\gamma$, or *Gamma*. About six degrees north-west of Caph, the telescope reveals to us a pretty large nebula of small stars, apparently compressed into one mass, with a number of loose stars surrounding it.

In the year 1604, about the end of September, another new star appeared near the heel of the right foot of *Serpentarius*. At that time, near the same part of the heavens, the planets Mars, Jupiter, and Saturn, were very near each other, a phenomenon which so engaged the attention of astronomers that no uncommon appearance in that quarter of the heavens could long have escaped detection. On the 17th of September, Kepler, who wrote a treatise on this star, carefully observed the three planets; on the 23d, he again viewed Mars and Jupiter, then approaching to their conjunction; and one of his scholars made the same observation on the 27th. On the 28th, and on the 29th, which was the day when Mars and Jupiter were in conjunction, they were observed by *Mæstlinus* and others; but none of them as yet saw any thing of the new star. On the 30th, the sudden breaking of the clouds afforded one of Kepler's friends an opportunity of having a very short view of it; for in looking for Mars and Jupiter, he saw a bright star near them, which he had not seen before, but it was soon obscured by clouds. On the 2d, 3d, 4th, and 6th of October, it was seen by several persons in different places. On account of cloudy weather at Prague, where Kepler resided, he did not see it till the 8th of that month. All the observers agreed in this,—that it was exactly round, without any beard or tail; that it was exactly like one of the fixed stars; and that in the vividness of its lustre, and the quickness of its sparkling, it exceeded any thing they had ever seen before. As to its *colour*, it was remarked that it was every moment changing into the colours of the rainbow, as yellow, orange, purple, and red; but was generally white when at a little height above the vapours near the horizon. At its first appearance, it seemed larger than any of the fixed stars, and even surpassed Jupiter, which planet was near it during the whole of October, and by its steady light was easily distinguishable from this vehemently sparkling star. It continued of the same size and brilliancy during the whole of October. About the end of this month the sun was approaching that part of the heavens in which the star appeared, yet on the 30th it was so much brighter than Jupiter that Kepler could see it distinctly when Jupiter was imperceptible, on account of the light of the sun, though he was further from the sun's beams than the star. On the 6th and 8th of November it was seen by Kepler and others; and at Turin, on the 13th, which appears to have been the last time it was perceived before being overpowered by the solar rays. After emerging from the sun's rays, on the west, it was seen in the morning on the 24th December, and though it sparkled exceedingly, yet it was considerably diminished in magnitude, appearing however, larger than the bright star *An-*

*tares.* From the middle of January 1605, till the middle of March, it gradually diminished in brightness. In the beginning of April, it appeared like a star of the third magnitude, and continued nearly of the same size during the months of May, June, and July, and continued to sparkle more strongly than any other fixed star. On September 28th, a year after its first appearance, it was more brilliant than the star in the leg of Serpentarius, which is reckoned of the third magnitude. As it was at this time again approaching to the vicinity of the sun, it does not appear to have been seen after this period. In December, 1605. and January, 1606, cloudy weather prevented observations after it had emerged from the solar rays. Kepler concludes that it must have disappeared some time between October, 1605, and the following February, but on what day is uncertain. Like the former star which appeared in Cassiopeia, it had no parallax, and remained in the same point of the heavens.

None of the new stars whose phenomena we have described above have ever reappeared, the places which they occupied still remaining a blank. It is much to be regretted that the telescope was not invented at the periods when these stars appeared, as it might have been ascertained by that instrument whether they had any sensible diameters. At any rate, their gradual decrease of magnitude and lustre might have been traced by a good telescope for a long period, perhaps for years, after they disappeared to the naked eye, which must have led us to draw some conclusions respecting the cause which produced so extraordinary phenomena. Were such a remarkable phenomenon to happen in our times, when telescopes, micrometers, and other astronomical instruments have received so many exquisite improvements, so as to enable us to penetrate deep into the profundity of space, and to measure the smallest angles, a variety of additional facts and circumstances would doubtless be discovered in relation to phenomena and events so striking and sublime.*

The subject of new stars, such as those now described, which blazed forth with so extraordinary a brilliancy and so soon disappeared, naturally gives rise to solemn and interesting reflections. There is a mystery that hangs over such sublime phenomena which produces in the mind an anxious desire to behold the veil removed, and to investigate the reasons and causes of such stupendous events. "It is impossible," says Mrs. Sommerville, when alluding to the star of 1572, "to imagine any thing more tremendous than a conflagration that would be visible at such a distance." Whether there was any thing in the existing state of the body alluded to similar to what we call a *conflagration* may be justly doubted; but there was a splendour and luminosity concentrated in that point of the heavens where the star appeared which would more than equal the blaze of *twelve hundred thousand worlds* such as ours, were they all collected into one mass, and all at once wrapt in flames. Nay, it is not improbable that, were a globe as large as would fill the whole circumference of the earth's annual orbit to be lighted up with a splendour similar to that of the sun it would scarcely surpass in brilliancy and splendour the star to which we refer; for during the whole period of its continuing visible, it never appeared in the least to shift its position, though it was carefully watched by the astronomers of that age; and, consequently, the whole diameter of the earth's orbit, while the earth passed from one extremity of it to another, appeared only as a point at the vast distance at which the star was situated. These may appear bold positions, but they are in some measure warranted by the facts of the case, and they are perfectly consistent with what we know of many of the other astonishing operations of that Almighty Being who is "wonderful in counsel and excellent in working," and "whose ways," in providence and creation "are past finding out."

It is natural to inquire what may have been the cause of phenomena so extraordinary and sublime; but our limited views of creation and of the plans and purposes of its Omnipotent Contriver and Governor prevent us from arriving at any satisfactory conclusions. La Place says, in reference to this subject—"As to those stars which suddenly shine forth with a very vivid light, and then vanish, it may be supposed, with probability, that great conflagrations, occasioned by extraordinary causes, take place on their surfaces; and this supposition is confirmed by their change of colour, analogous to that which is presented to us on the earth by bodies which are consumed by fire."* But such an opinion, however great the astronomer who proposed it, appears quite unsatisfactory. We err egregiously when we attempt to compare the puny operations and conflagrations which happen on our globe with a scene so far transcending every thing

* Besides the above, the following instances of new stars may be noted:—In the year 1670, a new star was discovered by Hevelius and Anthelm, near the head of the Swan, which, after becoming invisible, reappeared, and after undergoing several singular fluctuations of light during two years, gradually vanished from the sight, and has never since been seen. Another new star is said to have been seen the same year at Paris, about the back of the Swan, which, after the space of fourteen days, vanished away.—Whiston's *Astronomical Lectures*, p. 45.

* *System of the World*, vol. i. p. 101.

we behold in this terrestrial sphere. The greatest conflagration that was ever witnessed on earth cannot bear the smallest proportion or similitude to an object which must have occupied a space more than ten hundred thousand times the solid contents of our globe; nor is it likely that the agents or elementary principles which produced the respective phenomena were at all similar.

The late Professor Vince, one of the most learned astronomers of his age, has the following remark:—"The disappearance of some stars may be the destruction of that system at the time appointed by the Deity for the probation of its inhabitants, and the appearance of new stars may be the formation of new systems for new races of beings then called into existence to adore the works of their Creator."* The late Dr. Mason Good seemed to indulge in a similar opinion. "Worlds, and systems of worlds," says he, "are not only perpetually creating, but also perpetually disappearing. It is an extraordinary fact that, within the period of the last century, not less than thirteen stars, in different constellations, seem to have totally perished, and ten new ones to have been created. In many instances it is unquestionable that the stars themselves, the supposed habitation of other kinds or orders of intelligent beings, together with the different planets by which it is probable they were surrounded, have utterly vanished, and the spots which they occupied in the heavens have become blanks. What has befallen other systems will assuredly befall our own. Of the time and the manner we know nothing; but the fact is incontrovertible—it is foretold by revelation—it is inscribed in the heavens—it is felt through the earth. Such is the awful and daily text; what, then, ought to be the comment?" Similar to these were the sentiments of the late professor Robinson, of Edinburgh:—"What has become of that dazzling star, surpassing Venus in brightness, which shone out all at once in November, 1572?"—"Such appearances in the heavens make it evident that, notwithstanding the wise provision made for maintaining that order and utility which we behold in our system, the day may come 'when the heavens shall pass away like a scroll that is folded up, when the stars in heaven shall fall, and the sun shall cease to give his light.' The sustaining hand of God is still necessary, and the present order and harmony which he has enabled us to understand and admire is wholly dependent on his will, and its duration is one of the unsearchable measures of his providence."

Such are the pious sentiments of the above-named respectable philosophers in reference to the subject under consideration; but it may be questioned whether they are altogether judicious, or correspondent to the perfections of the Creator and the arrangements he has made in the universe. They seem to take for granted that those stars which have blazed for awhile, and then disappeared, have been destroyed or annihilated. We are indeed informed that, in regard to our globe, a period is approaching when "the elements shall melt with fervent heat, and the earth and the works that are therein shall be burnt up." But such a conflagration cannot be justly compared to the splendours of those wonderful stars described above. At whatever period in the lapse of duration such an event may take place, it will be so far from being visible at the nearest star, that it would not be seen by such eyes as ours at the boundaries of our system. Besides, we are assured, in that revelation which announces it, that that awful event shall take place as one of the consequences of the sin and depravity of man; and therefore we have no reason to believe that it will extend to the sun or any of the surrounding planets of our system; nor have we any reason to conclude that the conflagration of our globe will issue in its entire destruction, or that the elementary principles of which it is composed will be annihilated. It is more probable, nay, almost certain, that this tremendous event will only tend to purify our globe from the physical evils which now exist, and to transform it into a new and happier world for the residence of renovated and pure intelligences. In regard to *annihilation*, we have no proof that any particle of matter which was ever created has yet been annihilated.* Incessant changes and transformations are going forward both in the scene of sublunary nature and throughout the celestial regions; but changes in material objects do not necessarily imply the *destruction* of the matter of which they are composed, but simply a new arrangement or mode of operation. We have no reason to believe that any portions of matter which now exist throughout the universe will ever be reduced to annihilation. On the other hand, we have palpable evidence, from several phenomena in the heavens, that the work of creation is still going forward, and that the Creator is gradually ushering into existence new suns, and systems, and worlds; and in all probablity his creating energy will be continually exerting itself throughout all the succeeding ages of eternity.

Again, if that grand and terrific event which is to put a final period to the present

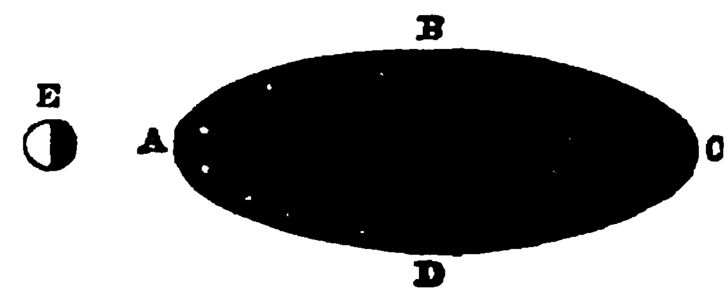
* Vince's "Complete System of Astronomy."

* See "Philosophy of a Future State," chap. i. sect. 10; and "Christian Philosopher."

terrestrial system is to be viewed as a consequence of the introduction of moral evil and the depravity of man, then we are led to conclude that those intelligences which were connected with the systems which are supposed to have been destroyed must have been involved in the guilt of moral degeneracy, or, in other words, in rebellion against their Creator; otherwise, why were they subjected to such an awful catastrophe, and doomed to be blotted out of existence? We have no ground for entertaining any such supposition. Reasoning from the *benevolence* of the Deity, it is more probable to conclude that the inhabitants of our world are almost the only intelligences throughout the universe who have swerved from the path of original rectitude, and violated the moral laws of their Maker. Nor is it likely that the *whole inhabitants* of any system, consisting, perhaps, of thirty or even of a hundred worlds—would be found uniting in rebellion against the moral government of their Benefactor, so as to warrant the *entire* destruction of the system with which they were connected. Besides, were the views of the philosophers to which I allude to be adopted, then we must admit that the systems which in their opinion were destroyed or annihilated must have been continued in existence only for a year or two; for no luminous bodies occupied the places of the new stars before they burst on a sudden to the view, and no twinkling orbs have been seen in these points of the heavens since they disappeared; but it is surely not at all probable that the Almighty would launch into existence systems of such amazing magnitude and splendour, and suffer them to rush into destruction within a period of so very limited duration.

For the reasons now stated, and others which might have been brought forward, I cannot acquiesce in the views of the respectable philosophers to which I have adverted; but it is easier to set aside an untenable hypothesis than to attempt an explanation of the real causes of so sublime and wonderful phenomena. In investigating the distant wonders of the universe and the arrangements of the Divine government, it becomes us to express our sentiments with modesty and caution. Whatever may have been the causes which produced the sudden splendour and the rapid disappearance of the new stars, I entertain not the least doubt that those bodies are still in existence, and subserving important purposes in the economy of God's universal government. Almost any hypothesis is to be preferred to that which supposes their destruction or annihilation. What should hinder us from concluding that the extraordinary phenomena of the star of 1572 was owing to a luminous orb of immense magnitude, accompanied with a retinue of worlds, *moving with inconceivable velocity in an immense elliptical orbit, the longer side of which was nearly in a direction to our eye;* that its most brilliant appearance was when it was nearerst our system, as at *A*, (fig. 10,) sup-

Fig. 10.




posing *E* the relative position of the earth, or of our system; and that, as it gradually declined in its brightness, it was passing along the curve from *A* towards *B* and *C*, till its rapid flight at length carried it beyond the limits of human vision? Had telescopes been in use at that period, there is little doubt it would have been seen, though still diminishing, for a much longer period than that in which it was visible to the unassisted eye; in which case it would have fully corroborated the opinion now stated. In confirmation of this explanation of the phenomena it has been supposed, with a high degree of probability, that it is the same star which appeared in the year 945 and in 1264, which, of course, would have a period of revolution of about 319 years, which period might vary two or three years in the course of its revolutions, from causes with which we are unacquainted, as we find sometimes happens in the case of comets. This opinion is rendered the more probable from the consideration that the stars of 945 and 1264 appeared in the constellation of *Cassiopeia*, where likewise the star of 1572 was observed; and if these be identical, then it is probable that it will again make its appearance about the year 1891 or 1892; and if so, astronomers will then have a better opportunity of marking its aspects and motions, and determining its size and its period of revolution.

If this explanation appear the most probable, it presents to the mind a most magnificent and overwhelming idea, without supposing any thing so tremendous and terrific as a sudden conflagration. It presents before us a luminous globe of astonishing magnitude—perhaps not less than a hundred times the size of our sun—winging its course over a circuit perhaps a thousand times more expansive than the orbit of Uranus, and carrying along with it a hundred worlds in its swift career. The motion of such a body must

have been rapid in the extreme, when we consider the rapid diminution of its apparent magnitude. In the month of November it first appeared; in December its brightness was sensibly diminished; in the month of April following it had diminished to the size of a star of the second magnitude; in July, to one of the third magnitude; in October, to one of the fourth; in the following January, to one of the fifth; in February, to one of the sixth magnitude; and in March it disappeared.

Now, according to Sir W. Herschel's experiments, the light of a star of the *first* magnitude being supposed 100, the light of one of the second magnitude is 25, one of the *third* magnitude, 12, &c. (see p. 25.) If, then, we suppose these classes of stars to be nearly of equal magnitudes, and that their distance is in an inverse proportion to the diminution of their light, it will follow that a star of the second magnitude is four times the distance of a star of the first; a star of the third magnitude, four times the distance of the second, or eight times the distance of the first magnitude, &c, Supposing, then, the star of 1572 to have been twenty billions of miles from the earth at its nearest approach to our system: from December, 1572, to April, 1573, when it was diminished to the apparent size of a star of the second magnitude, it must have moved four times that distance, or eighty billions of miles during these four months, which is at the rate of six hundred thousand millions of miles a day, and four hundred and sixty-two millions a minute, a velocity of which we can have no adequate conception.

If the above explanation be unsatisfactory, I know not to what hypothesis to resort for a solution of this mysterious and wonderful phenomenon. Whatever view we may be disposed to take of such striking events, we are lost in admiration and wonder. We behold a display of magnitude, of motion, and of magnificence, which overpowers the human faculties, which shows us the littleness of man and the limited nature of his powers, and which ought to inspire us with reverence of that Almighty Being who sits on the throne of the universe, directing all its movements for the accomplishment of his wise and righteous designs, and for the diffusion of universal happiness throughout all the ranks of intelligent existence. However astonishing the conclusions we are led to deduce from the phenomena under consideration, the facts to which we have adverted are not beyond the energies of Him whose perfections are strictly *infinite*. Nay, from such a Being, who is self-existent and omniscient, who fills the immensity of space with his presence, and whose power is boundless in its operation, we should naturally expect that displays of creating and sustaining energy would be exhibited, altogether overwhelming and incomprehensible by mortals. "Canst thou by searching find out God? Canst thou find out the almighty perfection? In the heights of heaven he doth great things past finding out, yea, and wonders without number. By his spirit he hath garnished the heavens. The pillars of heaven tremble and are astonished at his reproof. Lo, these are but parts of his ways; but the thunder of his power who can understand?"

## CHAPTER VII.

### *On Variable Stars.*

When the starry firmament is attentively surveyed, and the aspects of the numerous orbs it contains particularly marked, it is found that several of these bodies are subject to periodical changes in the brilliancy of their light and their apparent diameters, indicating in some instances motions and revolutions of considerable extent. The following sketches contain descriptions of the more remarkable phenomena connected with this class of the heavenly bodies, generally known by the name of *variable*, or *periodical* stars:

The first star of this kind which seems to have been particularly noticed is one in the neck of the Whale, whose right ascension is $2^h\ 8'\ 33''$, and south declination, $3^\circ\ 57'\ 25''$. It was first observed on August 13th, 1596, by David Fabricius, when it appeared like a star of the third magnitude, but disappeared after the month of October in the same year. It was again observed by Holwarda in the year 1637; and after having disappeared during a period of nine months, it again became visible; since which time it has been found every year pretty regular in its period, except from October, 1672, to December, 1676, during which time Hevelius could not perceive it, though it was a particular object of his attention. Bullialdus, a Frenchman, having compared together the observations that had been made on it from 1638 to 1666, determined the periodical time between its appearing in its greatest brightness and returning to it again to be 333 days. He found also that about 120 days elapse between the time that it is first seen of the sixth magnitude and its disappear-

ing; that it continues in its greatest lustre for about fifteen days; that after its first reappearance of the sixth magnitude it increases in size much faster till it come to be of the fourth magnitude, than it does from that period to its being of the third; and that from its being of the third it increases to the second magnitude by still slower degrees. Modern astronomers give the following description:—"It remains in its greatest brightness about a fortnight, being then nearly equal to a star of the second magnitude; it decreases during three months, till it becomes completely invisible, in which state it remains about five months, when it again becomes visible, and continues increasing during the remaining three months of its period; but it does not always return to the same degree of brightness, nor increase and diminish by the same gradations." It appears about twelve times in eleven years. Cassini determined its period to be 334 days; but Sir W. Herschel makes it 331 days, 10 hours, 19 minutes. It appears, then, that this star passes through all the gradations of light and magnitude from a star of the second to a star of the sixth magnitude and under; but after it has disappeared to the naked eye it may be traced to its lowest magnitude by a telescope of moderate power. It is sometimes distinguished by the name of *Stella Mira*, or the wonderful star, and *Omicron Ceti*.

In 1704, Maraldi observed a variable star in the constellation *Hydra*. This star had been described by Montanari in 1670, but was not visible in April, 1702. Maraldi saw it for the first time in the beginning of March, 1704, in the same place where it had been seen thirty-four years before. It appeared of the fourth magnitude, and continued nearly in the same state till the beginning of April. It then gradually diminished till the end of May, when it could no longer be seen by the naked eye, but was visible through the telescope for a month longer. It could not be seen again till the end of November, 1705, when that part of the heavens began to emerge from the sun's rays. It was then very faint, and grew less and less till the end of February, 1706, and could then be scarcely perceived even with a telescope. It did not reappear till the 18th of April, 1708, when it was larger than a star of the sixth magnitude, and increasing in lustre. It was seen by the same observer afterwards, in the years 1709 and 1712. From the observations of Maraldi, Mr. Pigot concludes that its period was then 494 days; but from observations made by himself, he thinks that *now* it is only 487 days; so that from the time of Maraldi it has shortened seven days. The following are the more prominent particulars relating to this star:—1. When at its full brightness it is of the fourth magnitude, and does not perceptibly change for the space of fourteen days. 2. It is about six months in increasing from the tenth magnitude and returning to the same; so that it may be considered as invisible during that time. 3. It is considerably more quick, perhaps one-half more so, in its increase than in its decrease. 4. Though, when at its full, it may always be styled a star of the fourth magnitude, it does not constantly attain the same degree of brightness, but the differences are very small. 5. Its right ascension for 1786 is $31^h\ 18'\ 4''$; and its south declination, $22°\ 9'\ 38''$. It is marked No. 30 in Hevelius' Catalogue of the Stars; from which data, its place may easily be found on a planisphere, or on the celestial globe.

In the year 1600, G. Jansonius discovered a variable star in the breast of the Swan, which was afterwards observed by different astronomers, and supposed to have a period of about ten years. The results of Mr. Pigot's calculations from the observations of former astronomers are—1. That it continues in full lustre for five years. 2. It decreases rapidly for two years. 3. It is invisible to the naked eye for four years. 4. It increases slowly during seven years. 5. All these changes are completed in eighteen years. 6. It was at its minimum at the end of the year 1663. 7. It does not always increase to the same degree of brightness, being sometimes of the third, and at others only of the sixth magnitude. "I am entirely ignorant," says Mr. Pigot, "whether it is subject to the same changes in this century, having not met with any series of observations upon it; but if the above conjectures are right, it will be at its minimum in a very few years. Since November, 1781, to the year 1786, I have constantly seen it of the sixth magnitude, though I suspect that in 1785–6, it had rather decreased." This star is near *Gamma* in the Swan's breast: it varies from the third to the sixth, seventh, &c. magnitudes. Its right ascension is $20^h\ 9'\ 54''$; north declination, $37°\ 22'\ 37''$.

One of the most remarkable of these changeable stars is that called *Algol*, in the head of Medusa, in the constellation *Perseus*. It had long since been known to appear of different magnitudes at different times; but its period was first ascertained by John Goodricke, Esq., of York, who began to observe it in the beginning of the year 1783. It changes continually from the first or second to the fourth magnitude; and the time which elapses from one greatest diminution to the other was found in 1783 to be, at a mean, 2 days, 20 hours, 49 minutes. The change is thus—during four hours it gradually diminishes in lustre; during the succeeding four

hours it recovers its first magnitude by a like gradual increase; and during the remaining part of the period, namely, 2 days, 12 hours, 42 minutes, it invariably preserves its greatest lustre; after the expiration of which its diminution again commences. According to Mr. Pigot, who has made many observations on such stars, and paid particular attention to the subject, the degree of brightness of this star when at its *minimum* is variable at different periods; and he is of the same opinion in regard to its brightness when at its full; but whether these differences return regularly or not has not been determined. The right ascension of Algol, or β *Persei*, for 1786, is $2^h$ 54′ 19″; and its north declination, 40° 6′ 58″. It is situated 12° east of *Almaach*, in the foot of Andromeda, and may be known by means of three stars of the fourth magnitude lying a few degrees south-west of it, and forming a small triangle. It comes to the meridian on the 21st December, about nine o'clock in the evening; but as it continues above the horizon at least twenty hours out of the twenty-four, it may be seen every evening from August to May.

Another variable star is to be found in the neck of the Swan. The period of this star has been settled by Maraldi and Cassini at 405 days; but from a mean of the observations of Mr. Pigot, it appears to be only 392, or at most 396⅞ days. The particulars relating to it are,—1. When at its full brightness, it undergoes no perceptible change for a fortnight. 2. It is about three and a half months in increasing from the eleventh magnitude to its full brightness, and the same in decreasing; for which reason it may be considered as invisible during six months. 3. It does not always attain the same degree of lustre, being sometimes of the 5th and sometimes of the seventh magnitude. The right ascension of this star is $19^h$ 42′ 21″; and its north declination, 32° 22′ 58″. It is situated in the neck, and nearly equi-distant from *Beta* and *Gamma*, and south by west from *Deneb*, at the distance of about twelve degrees, and is marked *Chi*.

The star *Eta* Antinoi is another star of this description, whose variation and period were discovered by Mr. Pigot in 1785. From his corrected observations, he concludes that it continues at its greatest brightness forty hours without decreasing; it is sixty-six hours after it begins to decrease before it comes to its full diminution; after which it continues stationary for thirty hours more; and then increases for thirty-six hours. In every period it seems to acquire its full brightness, and to be equally decreased. Its period therefore is seven days, four hours; and its greatest and least variation is from the third to the fifth magnitude. Its right ascension is $19^h$ 41′ 34″; and its north declination 0° 28′ 14″. It is about eight degrees south from *Altair*, the principal star in the constellation Aquila.

The above descriptions may suffice as specimens of the phenomena of variable stars. There are about seven or eight other stars which have been observed to be certainly variable, among which are the following:—A star in the Northern Crown, whose right ascension is $15^h$ 40′ 11″; north declination, 28° 49′ 30″; and period, 10½ months. A star in Hercules, whose right ascension is $17^h$ 4′ 54″; north declination, 14° 38′; and period of variation 60¼ days. A star in Sobeiski's Shield, whose right ascension is $18^h$ 36′ 38″; south declination, 5° 56′; and period 62 days. The star *Beta* Lyræ—right ascension, $18^h$ 42′ 11″; north declination, 33° 7′ 46″; greatest and least variation, 3, 4, 5; supposed period, 6 days, 9 hours. The star *Delta Cephei*, whose period is 5 days, 8½ hours; right ascension, $22^h$ 21′; and north declination, 57° 50′. With several others.

Besides these, whose variations and periods have been determined, there are about thirty-seven other stars, which are, with good reason, suspected to be variable, but whose periods of change have not yet been ascertained, on account of the want of a sufficient number of observers, who might devote their attention more particularly to this department of astronomical observation. For example, the star *Pollux*, or *Beta* Gemini, is suspected to change from the first to the third magnitude.

When contemplating such changes among bodies so immensely distant, and of so vast magnitude, we are naturally led to inquire into the causes which produce those phenomena. Our ignorance, however, of the precise nature and constitution of those remote bodies, and of the scenes and circumstances in which they may be placed, prevent us from forming any definite or satisfactory conclusions. The following are some of the opinions which have been thrown out on this subject. It has been supposed that portions of the surfaces of these stars are covered with large black spots, which, during the diurnal rotation of the star, present themselves under various angles, and thus produce a gradual variation in its brilliancy. Sir W. Herschel says "Such a motion may be as evidently proved as the diurnal motion of the earth. Dark spots, or large portions of the surface less luminous than the rest, turned alternately in certain directions, either towards or from us, will account for all the phenomena of periodical changes in the lustre of the stars so satisfactorily, that we certainly need not look for any other cause." Sir Isaac Newton thought that the sudden blaze of some stars

may have been occasioned by "the falling of a comet into them, by which means they would be enabled to cast a prodigious light for a little time, after which they would gradually return to their former state." But we know too little about the nature of comets to be able to determine what effect they would produce in such a case, nor are we certain that such bodies are connected with other systems. If the fixed stars be nearly of the same nature as the sun, it is highly improbable that any such effect would be produced even although a comet were to fall into its luminous atmosphere, as that atmosphere appears to have nothing in it that would take fire by the approach of any extraneous body, or that would "blaze" like combustible substances on the earth. The blaze, if such an effect were to take place, would scarcely be distinguishable from our globe, and much less from a distant system. Maupertius, in a "Dissertation on the Figures of the Celestial Bodies," is of opinion that some stars, by their prodigious quick rotation on their axes, may not only assume the figures of oblate spheroids, but that, by the great centrifugal force arising from such rotations, they may become of the figures of millstones, or be reduced to flat circular planes, so thin as to be quite invisible when their edges are turned towards us, as Saturn's ring is in such positions. And when any eccentric planets or comets go round any fixed star, in orbits much inclined to its equator, the attraction of the planets or comets in their perihelions must alter the inclination of the axis of that star; on which account it will appear more or less large and luminous, as its broadside is turned more or less towards us. This opinion, at best, I consider as having a very small degree of probability, and almost quite untenable. Mr. Dunn, in a paper in vol. 52 of the "Philosophical Transactions," supposes that the interposition of some gross atmosphere may solve the phenomena under consideration. "The appearance of new stars," says he, "and the disappearance of others, possibly may be occasioned by the interposition of such an ethereal medium within their respective orbs as either admits light to pass freely or wholly absorbs it at certain times, whilst light is constantly pursuing its journey through the vast regions of space."

Whatever opinions we may adopt on this subject, it is evident that *the regular succession of the variations* of periodical stars preclude the idea of their being destroyed. It is likewise evident that *motion* of some kind or other, either in the stars themselves or in some bodies either directly or remotely connected with them, must be one of the causes of the phenomena in question; and it is not improbable that different causes in different instances may operate in producing the effect. It does not appear to me probable that the cause which produces the variation in the case of *Delta Cephei*, whose period is only 5 days, 8½ hours, is the same which produces all the variety of change which happens in the star *Gamma* in the Swan's breast, whose periodical changes are completed only in eighteen years. It is not unlikely that a rotation round an axis, which has the effect of presenting different sides of the star of more or less degrees of obscurity or brightness to the eye of a spectator, will account for the phenomena of such stars as *Eta* Antinoi and *Delta Cephei*; but it does not appear probable that a motion of rotation is so slow in any of these bodies as to occupy a period of eighteen years, as in the case of the star in the breast of the Swan.

I am disposed to consider it as highly probable that *the interposition of the opaque bodies of large planets revolving around such stars* may, in some cases, account for the phenomena. It is true that the planets connected with the solar system are so small in comparison of the sun that their interposition between that orb and a spectator at an immense distance would produce no sensible effect. But we have no reason to conclude that in all other systems the planets are formed in the same proportion to their central orbs as ours; but, from the variety we perceive in every part of nature both in heaven and earth, we have reason to conclude that every system of the universe is in some respect different from another. There is no improbability in admitting that the planets which revolve round some of the stars may be so large as to bear a considerable proportion (perhaps one-half or one-third) to the diameters of the orbs around which they revolve; in which case, if the plane of their orbit lie nearly in the line of our vision, they would in certain parts of their revolutions interpose between our eye and the stars, so as to hide for a time a portion of their surfaces from our view, while in that part of their orbits which is next the earth Such a supposition is by no means inconsistent with the operation of the law of universal gravitation; for although such planets bore a considerable portion of the size of their central luminaries, yet we have only to suppose that their *destiny* is *very small*. They may be globes whose central parts are devoid of solid matter, consisting only of a solid external shell for the support of inhabitants, as is probably the case with the planet Saturn, whose density is only equal to that of cork.

A planet about the size we have now supposed revolving around a star would, in a great measure, account for the phenomena presented by *Algol*. This star accomplishes

the period of its variations in 2 days and nearly 21 hours. During 3½ or 4 hours it gradually diminishes in lustre, and during the succeeding four hours it gradually recovers its first magnitude. Throughout the remaining part of the period—namely, 2 days, 12 hours, 42 minutes,—it invariably preserves its greatest lustre; so that the time of its being diminished in lustre is only about the ninth part of its whole period of variation. Now supposing a planet about half the diameter of the star revolving around Algol, it would intercept a

Fig. 11.

large portion of its surface when it passed between our eye and the star, as at *a*, *b*, (fig. 11,) where the white circular ring represents the suface of the star partly covered by the planet. Its lustre would begin to diminish when the planet entered on its edge at *d*, and it would again resume its full brightness when going off at *c*, the dark side of the planet being of course turned to our eye; and during the remaining part of its revolution it would appear in its brightest lustre. The regularity of the changes of this star admits of the supposition now made, and evidently requires a regular motion of some kind or other, either in the star itself or in some body connected with it, in order to produce the phenomena. Perhaps, in the case of some of the variable stars, we might suppose several large planets in succession to pass between our eye and the star to account for the appearance they present—a supposition which perfectly agrees with the idea of a *system* of revolving bodies.

As it is not probable that the changes of all such stars arise from the same cause, what should hinder us from supposing that *there are stars or suns that revolve around planets of a size immensely greater*,—the planets, for example, bearing a similiar proportion to the stars as the sun bears to Jupiter? Considering the immense variety of celestial mechanism throughout the universe, there can be no great improbability in such a supposition. The case of *double stars* demonstrates that one sun actually revolves round another; and why may not a sun revolve around a central planet, whose surface may contain forty times the area of all the planets of our system, in order to distribute light and heat, and other beneficial influences, to its numerous population? No violation of the law of universal gravitation is implied in such a supposition; and the Almighty is not confined to one mode of arranging systems and worlds. Supposing, then, such an arrangement to exist, it might account for the phenomena of some of the variable stars, particularly those which remain invisible for a certain period. Such are some of those formerly noticed, as the star in Hydra, and that in the breast of the Swan, and particularly a star in the Northern Crown, whose right ascen. is 15h 40′, north declin. 28° 49½′, and period 10½ months, and which decreases from the sixth to the ninth and tenth magnitude. It attained its full brightness about the 11th of August, 1795, and continued so for three weeks; in 3½ weeks it decreased to the tenth magnitude, and a few days afterwards disappeared. After being a considerable time invisible, in April, 1796, it again appeared; on the 7th of May, it reached the ninth magnitude, and then gradually attained its full brightness. If, then, such a star was revolving round a very large central planet, it is easy to conceive that in the more distant part of its course it might be hid from our view, either in whole or in part, by the interposition of the opaque central body, as is obvious from an inspection of figure 12. And as the star now alluded to never exceeds in lustre a star of the sixth magnitude, it is not improbable that it is one of the inferior order of those luminous orbs which may revolve round an opaque body of superior magnitude.

Fig. 12.

Such, then, are some of the conceivable causes which may produce the phenomena of variable stars, although other causes may in some cases exist of which we have no con-

ception. These phenomena evidently indicate that motions and revolutions of various kinds are going forward throughout the stellar regions; that the Almighty is superintending the movements of those provinces of his empire, and that all his agencies have a respect to the order and the happiness of intelligent existence.

Besides the periodical variations to which we have now adverted, there are several other striking changes which have been observed in the starry regions which deserve our attention, and which I shall briefly notice.

1. Several stars which were formerly distinctly visible, and are marked in different catalogues, are now wholly lost. The following are a few instances. M. Montanere, professor of mathematics at Bononia, in a letter to the Royal Society, of date April 1670, gives the following statement: — "There are now wanting in the heavens two stars of the second magnitude, in the stern and yard of the ship Argo. I and others observed them in the year 1664, upon occasion of the comet that appeared that year. When they disappeared first I know not; only I am sure that, in the year 1668, upon the 10th of April, there was not the least glimpse of them to be seen, and yet the other stars about them, of the third and fourth magnitudes, remained the same. I have observed many more changes among the fixed stars, even to the number of a hundred, though none of them are so great as those I have showed." In 1670, Anthelm discovered a star of the third magnitude in the head of the Swan, which after becoming completely invisible, reappeared, and after undergoing one or two singular fluctuations of light during two years, at last died away entirely, and has not since been seen. Sir. William Herschel gives a list of thirteen stars, most of which are supposed to be lost. Of these are the following:—Nos. 80 and 81 of Hercules, both of the fourth magnitude; the 19th of Perseus, of the sixth magnitude; and the 108 Pisces, are judged to be wholly lost. The stars 73, 74 Cancer, in the southern claw of the Crab, of the sixth magnitude, are either lost or have suffered such great changes that they can no longer be found. On this subject Sir John Herschel states—"The star 42 Virginis is inserted in the catalogue of the Astronomical Society from Zach's Zodiacal Catalogue. I missed it on the 9th of May, 1828, and have since repeatedly had its place in the field of view of my twenty feet reflector without perceiving it, unless it be one of two equal stars of the 9th magnitude very nearly in the place it must have occupied."

2. Some stars have changed their magnitudes since the beginning of last century. A considerable number of stars marked by Flamstead, in his *Historia Celestis*, are now found to be of different magnitudes since the period in which he observed the heavens and formed his catalogue. For example; the 1st and 2d of *Hydra* are now only of the eighth or ninth magnitude instead of the fourth, as they are marked by Flamstead. The 31st and 34th of *Draco* have changed greatly; the 31st has increased from the seventh to the fourth, and the 34th has diminished from the fourth to the sixth or seventh magnitude. The 38th Perseus, instead of the sixth, has now increased to the fourth magnitude. About thirty stars of this description are reckoned by Sir W. Herschel to have changed their magnitudes.

3. There are stars unknown to the observers of former times which have recently become visible. The following, among others of this description, have been marked by Sir W. Herschel:—1. A star in the end of the Lizard's tail, of the fourth or fifth magnitude, which is not recorded by Flamstead, although he notices one in that constellation less conspicuous. 2. A star near the head of Cepheus. 3. A considerable star in a direction from the 68th to the 61st of Gemini. 4. A star of considerable brightness preceding the 1st of the Little Horse. 5. A remarkable star between $\beta$ and $\delta$ Hydrae. 6. A star near $\delta$ Hercules, of the fourth or fifth magnitude, with several others. Similar observations appear to have been made about the end of the seventeenth and the beginning of the eighteenth centuries, by Cassini and others. Cassini discovered a new star of the fourth, and two of the fifth magnitude in Cassiopeia; two in the constellation Eridanus, one of the fourth, the other of the fifth magnitude; and four of the fifth and sixth magnitude near the north pole, which had not been perceived at a former period.

Such changes in bodies so far removed from our system, and of magnitudes so enormous as the least of them must be, naturally lead to the conclusion that revolutions of vast extent, and operations conducted on a most magnificent scale, are incessantly going forward in those remote and unexplorable regions. In the case of stars which have totally disappeared, we are led to conclude, either that some vast and important change has taken place in the *constitution* of certain worlds or systems, or that the central luminaries of such systems, with all their surrounding planets, have been transported by some unknown and almighty agency into more distant regions of space, where they may remain for ever hid from our view. As to those stars which have changed their magnitudes within the last century, they may either be approaching to or receding from the system to which

we belong, or their native brightness may be either increasing or diminishing from causes with which we are unacquainted; or some ethereal mediums of a peculiar nature may be interposed between our sight and those distant orbs. With respect to stars unknown to former observers which have recently become visible, it is not unreasonable to suppose that these are *new systems* recently launched from the creating hand of the Omnipotent, to diversify his creation and augment the glories of his empire, as well as to distribute happiness among new orders of sensitive and intelligent existence. We ought not to imagine that the work of creation, considered as a whole, is yet finished, or ever will be finished during an indefinite lapse of ages. When it is stated by the inspired writer of the book of Genesis that "God rested from all his work," we are to understand the expression only in reference to the formation or *arrangement* of the world in which we reside into the form and order in which we now behold it; for to this arrangement chiefly, if not solely, the descriptions of the sacred historian in the first chapter of Genesis refer. It is in perfect accordance with the idea of a Being possessed of omnipotent power, boundless goodness, and endless duration, that his creating energies should never cease in their operation throughout all the periods of an interminable existence; and the phenomena to which we refer are a strong presumption, if not a demonstrative evidence, of a continued series of creations. These new creations may be bursting forth in the remote spaces of the universe, in various degrees of splendour and magnificence, to an extent of which we have no conception; and from the character and perfections of the Divinity, we have reason to believe that such processes will be incessantly going forward throughout all the ages of eternity.

Whatever opinions we may be disposed to form as to the phenomena to which we have adverted, they tend to convey to the reflecting mind magnificent views of the physical energies of the Almighty, in arranging the different departments of his boundless dominions, and accomplishing the purposes and plans of his moral government, and they naturally excite in the mind a desire of future existence, and an ardent wish to behold the veil which now intercepts our views of these glorious orbs withdrawn, and to contemplate the scene of divine operation in all its splendour and magnificence.

At first view, it may appear a circumstance of comparative insignificance to behold a small star, scarcely distinguishable to the eye, waxing brighter, or growing dimmer, or vanishing altogether from the view; or a star appearing in a point of the heavens which was unoccupied before. The distant blaze of a field of furze, the falling of a tower, or the conflagration of a cottage, may to some appear events of far greater interest and importance; but such events in the heavens as those to which we refer may be connected with scenes as astonishing—though perhaps not so tremendous—as if the sun were shorn of his rays and turned into darkness, and this earth and all the planetary globes shattered to their centres and wrapped in flames; or, as if a new sun of superior magnitude were to appear in our system, and to illuminate our globes with a new species of light and colours. Objects at a great distance from the observer make little impression on the organs of vision, and seldom affect the mind. A fleet of the largest ships of war viewed from the top of a tower at fifty miles distance appears only like a few almost undistinguishable specks on the verge of the horizon, while the fate of individuals, families, communities, and even empires, may depend upon the encounter in which they may be engaged. The conflagration of a city of ten hundred thousands of inhabitants may appear at a distance as only a faint glimpse of light in one point of the horizon, while palaces, and temples, and thousands of splendid fabrics are turned into smoking ruins, and multitudes are thrown into the utmost consternation, and perishing in the flames. The burning of the city of Moscow, as beheld from the moon when the dark side of the earth was presented to that orb, would appear only like a dim lucid speck, scarcely distinguishable from the other parts of the earth's surface. And if this be the case in respect to objects within such limited distances, what astonishing scenes may be the result of what we perceive in bodies many thousands of millions of miles distant, when we behold them disappearing to our view, or even when we perceive their light only increasing or diminishing? Here imagination is left to fill up the picture which the organs of vision so dimly perceive. We are to consider that the orbs to which we allude are luminous globes of immense size,—that they are doubtless encircled with a retinue of worlds replenished with inhabitants,—that what to us appears a slight change of aspect may to them be the commencement of an era of new glory and splendour,—that the Almighty rules over those distant regions as well as "among the inhabitants of the earth,"—and that all the changes which happen among them are in unison with his eternal designs, and subserve the ends of his universal government.

## CHAPTER VIII.

### *On Double Stars and Binary Systems.*

In whatever part of creation we survey the operations of the Almighty, we uniformly find the characteristic of *variety* impressed upon all his works. This is evident in all the kingdoms of nature connected with our globe, where the multitude and diversity of animals, vegetables, and minerals, cannot but strike the eye even of the most superficial observer. Though the same general laws appear to pervade the material universe, so far as our observation extends, yet these laws are so comprehensive and so endlessly modified as to produce an immense variety of minute and wonderful effects. It is more difficult to trace the operation of these laws in the remote spaces of the universe than in our terrestrial sphere. But even in regions of creation immeasurably distant we can perceive the agency of the same powers which are at work in conducting the movements of our planetary system; and not only so, but we can trace these powers, while operating with their native energy, wonderfully modified, and producing effects altogether different from those which we experience in the system of which we form a part, evidently indicating that a *variety*, analogous to that which we behold in the scene around us, marks the operations of the Creator throughout the immensity of his works. This will more clearly appear in the descriptions we shall now give of the phenomena of double and multiple stars.

The phenomena of double stars do not seem to have been much attended to till Sir W. Herschel commenced his extensive observations on the sidereal heavens. About a century ago, the astronomers of that period seem to have been aware that "several stars which appear single to the bare eye are by the telescope discovered to be double." The principal stars of this description which they mention are,—the head of Castor, the first in the head of the Ram, the star *Gamma* in the breast of Virgo, and the middle one in the sword of Orion. Conceiving the fixed stars as bodies precisely of the same nature, and that no specific or diversified arrangements prevailed among them, they do not appear to have entered upon any minute surveys, by the telescope, of particular stars; and their idea respecting the double stars they had detected was merely this,—that a small star, at a very remote distance from another, might happen accidentally to lie nearly in the same line of vision as the larger one; and, on this ground, Dr. Long, in his "Astronomy," shows how the annual parallax would be discovered by a star appearing single at one time of the year, and double at another. It appears to have been chiefly with an object of this kind in view that Sir William Herschel commenced his numerous observations in this department of sidereal investigation. But, as we are informed by his son, who has distinguished himself in an eminent manner by similar observations, he had hardly entered on the measurements of the angles of position, and the distances of double stars, before he was diverted from the original object of his inquiry by phenomena of a very unexpected character, which at once engrossed his whole attention. The circumstances alluded to shall be particularly described in the sequel, after I have given a brief sketch of the phenomena of double stars.

When a telescope of considerable power is directed to certain stars which appear single to the naked eye, another star, generally much smaller than that which appears to the unassisted eye, is seen quite adjacent to it, and in some cases the interval between the two stars is so small that it requires a very high degree of light and magnifying power to be able to perceive that they are two distinct bodies. Only a few, perhaps not exceeding six or eight, of these stars were known to the astronomers of the age preceding that of Herschel; but this illustrious astronomer, with unwearied perseverance, detected no less than 500 double stars, and presented to the Royal Society a list in which their situation and relative positions are distinctly marked. These observations of the elder Herschel were followed up by other observers, particularly by Sir J. Herschel and Sir James South, who, in the year 1824, soon after Sir W. Herschel had ceased from his labours, produced a catalogue of 380 double stars, whose distances and angles of position they had determined with the utmost accuracy and precision. Sir J. South afterwards produced a *distinct* catalogue of 480, and Sir J. Herschel a list of upwards of 3300 of double and triple stars, from his own solitary observations, accompanied with all the micrometrical measurements.

Struve, the celebrated astronomer of Dorpat, has arranged a catalogue of no less than 3000 double stars; and before he determined the characteristics of each of these, he examined about 120,000 stars—a laborious process, which none but an astronomical observer can duly appreciate. Mr. Dunlop has formed a catalogue of 250 double stars in the *southern* hemisphere; and Sir J. Herschel, during his late residence at the Cape of Good Hope, has added considerably to their number; so that we may now reckon about 6000 of these interesting objects as having already been discovered, even making allowance that many of these objects are common to the lists of the observers now specified.

It is not at all improbable that the phenomena of some of the double stars now alluded to may arise from *accidental proximity*, the one star, though far remote and unconnected with the other, lying nearly in the same visual line. Thus, the star *a*, fig. 13, might appear nearly in contact with the star *b*, placed at an immense distance beyond it, when viewed nearly in the same straight line by the eye at *c*, so as to produce the phenomena of a

Fig. 13.


double star at *d b*. But, reasoning *a priori*, it appears in the highest degree improbable that such coincidences should happen in the case of all, or even of the greater part of the double stars which have now been discovered; and therefore Mr. Michell, so early as the year 1783, in a paper inserted in the "Philosophical Transactions" for that year, states it as his opinion that they are binary systems intimately connected. "The very great number of stars," says he, "that have been discovered to be double, treble, &c., particularly by Mr. Herschel, if we apply the doctrine of chances, as I have done in my 'Inquiry into the probable Parallax of the Fixed Stars,' published in the Philosophical Transactions for 1767, cannot leave a doubt with any one properly acquainted with the force of those arguments, that by far the greatest part, if not all of them, are systems of stars so near each other as probably to be liable to be affected sensibly by their mutual gravitation; and it is therefore not unlikely that the periods of the revolutions of some of these about their principals may some time or other be discovered."

The prediction here announced by this ingenious gentleman has now been fully realized by Sir William Herschel and other astronomers, and is no longer a subject of conjecture, but *an ascertained fact*. This is the discovery to which I have alluded above, one of the most important and interesting discoveries which astronomy has unfolded during the present age, and which opens to our view a new prospect of the plans and arrangements of Infinite Wisdom.

Having made these preliminary remarks, I shall now proceed to a more particular detail of the facts which have been ascertained respecting binary systems.

When Sir W. Herschel first directed his attention to this subject, in order if possible to determine the annual parallax, he was not a little surprised that, instead of finding, as he expected, a regular annual change of the two stars, by one alternately shifting its position with respect to the other, which a parallax would have produced, he observed in many instances "*a regular progressive change*, in some cases bearing chiefly on their distance, in others on their position, and advancing steadily in one direction, so as clearly to indicate either a real motion of the stars themselves, or a general rectilinear motion of the sun and whole solar system, producing a parallax of a higher order than would arise from the earth's orbital motion." In an elaborate paper on this subject, read before the Royal Society, June 9, 1803, he considers specifically all the motions and combinations of motion that can possibly be supposed, in order to account for the phenomena, particularly of the double star *Castor*, and satisfactorily demonstrates that nothing but the idea of the smaller star revolving around the larger in a circular or elliptical orbit will solve the phenomena in question; and this conclusion has been amply confirmed by all succeeding observations. Such stars therefore must be considered as *physically connected* by the law of mutual gravitation, so that they describe orbits around each other and around their common centre of gravity, and bear a relation to each other similar to that which the planets bear to our sun.

From the paper of Sir W. Herschel now referred to, I shall select, as a specimen of the motions of double stars, some of his observations of *Castor*, or *α Geminorum*. It appears that Dr. Bradley in the year 1759 had observed the position of the two stars which form this double star, and communicated it to Dr. Maskelyne, who made a memorandum of it, of which the following is a copy:—"Double star Castor. No change of position of the two stars; the line joining them at all times of the year, *parallel to the line joining Castor and Pollux* in the heavens, seen by the naked

eye." The object of Dr. Bradley in observing the exact position of these stars was, to determine if any change happened in their position at opposite periods of the year, so as to indicate an annual parallax. The angles of position observed by Sir W. Herschel are as follow:

| Times of the observations. | Angles of Position | |
|---|---|---|
| November 1, 1759 . . . . . | 56° | 32′ |
| November 5, 1779 . . . . . | 35 | 29 |
| February 23, 1791 . . . . . | 23 | 36 |
| December 15, 1795 . . . . . | 18 | 32 |
| March 26, 1800 . . . . . . | 14 | 9 |
| December 31, 1801 . . . . . | 12 | 12 |
| February 28, 1802 . . . . . | 12 | 1 |
| March 27, 1803 . . . . . . | 10 | 53 |

From these observations it appears that from the year 1759, when Dr. Bradley observed the positions of the two stars, to the year 1803, there has been a portion of an orbit described by the smaller star around the greater equal to forty-five degrees and thirty-nine minutes; and from the time that Herschel commenced his observations in 1779 till 1803, an arch of twenty-four degrees and thirty-six minutes had been passed over. Hence Sir W. Herschel concludes—"The time of a periodical revolution may now be calculated from the arch 45° 39′, which has been described in 43 years and 142 days. The regularity of the motion gives us great reason to conclude that the orbit in which the small star moves about Castor, or rather the orbits in which they both move round their common centre of gravity, are nearly circular and at right angles to the line in which we see them. If this should be nearly true, it follows that *the time of a whole apparent revolution of the small star round Castor will be about 342 years and two months.*" This subject may be illustrated to the general reader by the following diagram:

Fig. 14.

Let the small central circle *C* represent the larger star Castor, and *D* the smaller star, and let the line *E F* represent the direction of the two stars in a line with the star *Pollux*, at *E*, as observed by Dr. Bradley in 1759. In November, 1779, they were found in the position *C H*, twenty-one degrees from the position they occupied twenty years before; in February, 1791, they were thirty-three degrees from the same position, &c.; and in March, 1803, forty-six and a half degrees; giving evident indication of a regular progressive motion in a circle. Since 1803 its motion has been regularly traced by Struve, Sir J. Herschel, and Sir. J. South; and in 1816 it was found about 57° degrees from its first position, and in 1830 about 68°, still regularly progressing. In 1819, the distance of the small star from Castor was five seconds and a half, and in 1830 it was little more than four seconds and a half. Although Sir W. Herschel, as above stated, conjectured the period of revolution to be about 342 years, yet later astronomers, from a comparison of all the observations recently made, are disposed to conclude that its period is little more than 250 years.

More than fifty instances of changes in the angles of position of double stars were observed by Sir W. Herschel, besides those which have been more recently observed by his son and other astronomers, most of which indicate motions which are regularly *progressive*; but a considerable number of years must elapse before their periods can be determined with any degree of accuracy. The following double stars are considered as demonstrative instances of circular progressive motion:—$\gamma$ Virginis, $\xi$ Ursæ Majoris, 70 Ophiuchi, $\sigma$ and $\eta$ Coronæ, $\xi$ Bootis, $\eta$ Cassiopeiæ, $\gamma$ Leonis, $\zeta$ Herculis, $\delta$ Cygni, $\mu$ Bootis, $\epsilon$ 4 and $\epsilon$ 5 Lyræ $\lambda$ Ophiuchi, $\mu$ Draconis, $\epsilon$ Bootis, and $\zeta$ Aquarii. The periodic times of some of these have been determined to a near approximation. One of the stars of *Gamma* Virginis is reckoned to revolve about the other in the space of 629 years; the small star of *Gamma* Leonis, in 1200 years; the star connected with *Epsilon* Bootis, in 1600 years; that of 61 Cygni, in 452 years; that of *Sigma* Coronæ, in 287 years; that of 70 Ophiuchi, as ascertained by Professor Encke, in 80 years; that of *Xi* Ursæ, in 58 years; that of *Zeta* Cancri, in 55 years; and that of *Eta* Coronæ, in 43 years.

A whole revolution of some of these stars has been nearly completed since observations began to be made on such objects. The motion of the small star of *Xi* Ursæ began to be traced about the year 1781; in 1819, it had moved 219° from its position in 1781; in 1830, it was 303 from that position, progress-

ing in a circle; and about this time, or the beginning of 1840, it has probably finished its orbital revolution. The star *Eta* Coronæ, whose period is forty-three years, has not only accomplished a complete revolution, but is actually considerably advanced in its second period. Sir J. Herschel, during his late sojourn at the Cape of Good Hope, is said to have discovered in the southern skies, binary stars, whose periods of revolution are even shorter than those now stated, their change of position having been quite perceptible during the three or four years of his residence in that quarter. Sir W. Herschel, in the paper to which I have already referred, states observations which furnish us with a phenomenon which is new in astronomy—namely, *the occultation of one star by another.* With a power of 460, in July, 1782, the stars of *Zeta* Herculis were then half the diameter of the small star asunder; in 1795, he found it difficult to perceive the small star with the same power; in 1802, the small star could no longer be perceived, but the apparent disc of the large star seemed to be a little lengthened one way. With his ten feet telescope, and a power of 600, he found it to have the appearance of a wedge-formed star. On the 11th of April, 1803, he examined the apparent disc with a power of 2140, and found it, as before, a little distorted, but there could not be more than about three-fourths of the apparent diameter of the small star wanting to a complete occultation. "Most probably," he observes, "the path of the motion is not quite central; if so, the disc will remain a little distorted during the whole time of the conjunction." This phenomenon evidently demonstrates the fact of circular orbital motion, performed in a plane nearly parallel to our line of vision.

The star *Gamma* Virginis has presented phenomena nearly similar to that of *Zeta* Herculis. This star is remarkable both for the length of its period, the rapid increase of the angular motion of the two stars of which it is composed, and particularly *the great diminution of their apparent distance.* It has been known as a double star for at least 120 years. The two stars of which it is composed, and which are nearly equal, were so far apart about the middle of the last century that they were marked in Mayer's catalogue as two distinct stars, so that any moderately good telescope would have shown their separation, being at that period about seven seconds distant from each other. Since that time they have been constantly approaching, and in 1833 were scarcely more than a single second asunder; so that a common telescope was insufficient to show their separation, and even telescopes of very superior power could show them no otherwise than as a single star somewhat elongated. According to Sir J. Herschel's computations, the small star must have arrived at its perihelion on the 18th of August, 1834. He also determined *the inclination of the orbit to the visual ray* to be 22° 58′, *and the angle of position of the perihelion* projected on the heavens, 36° 24′. The small star of *Eta* Coronæ reached its perihelion in 1835; and it is calculated that the revolving star of Castor will reach the same point during the year 1855.

From the observations that have been made on binary stars, it now appears demonstrable that the law of gravitation extends its influence to the starry regions; that the same laws of motion which direct the planets in their courses, and connect them with the sun as their centre, likewise operate in these binary systems in carrying one star around the centre of gravity of another. It has often been surmised that gravitation is a power which is universal in its influence; and here we have a proof that it extends not only beyond the range of the planetary system and the orbits of the most eccentric comets, not only to stars reckoned the nearest to our globe, but to those of the third, fourth, and even tenth magnitudes, which may be supposed many hundreds of billions of miles further distant; thus rendering it highly probable that it is a fundamental law of matter, and extends its energies throughout the amplitudes of creation, combining in one vast system all the operations of the Eternal.

The orbits in which the one star moves around the other are found to be *elliptical*, which is the same kind of curve in which the earth and the other planets move round the sun, in which the satellites of Jupiter, Saturn, and Uranus perform their revolutions round their respective primaries—another proof that the same general law operates in both cases. Some of these orbital motions are *retrograde* and others are *direct*, or in the same direction as the motions of the planets of our system. In some cases it happens that the edge of the orbit of the revolving star is presented to the earth, or in a line nearly parallel to that of our vision, as is found in the star π Serpentarii; in which case the star appears to move in a straight line, and to oscillate on each side of the larger star around which it revolves, in a manner similiar to that of the satellites of Jupiter, which appear to pass from the one side to the other of the planet in nearly straight lines, because the plane of their orbits is nearly in a line with our eye. At the time when Sir W. Herschel first observed this binary system, the two stars were distinctly separate, but at present the small star is so completely projected on the other that even

struve, with his powerful telescope, cannot now perceive the least separation between the two bodies—a fact which evidently demonstrates that to our eye the one passing across the disc of the other, and that a number of years hence it will appear on the other side of the larger star. On the other hand, the two stars of *Zeta* Orionis are now separated by a small interval, although they appeared as one star in the time of Sir W. Herschel; all which phenomena demonstrate a motion in a circular or elliptical orbit, the plane of which lies *oblique* to our eye; and it has been calculated, from the apparent motions of these bodies, that the ellipses in which they move are in general more elongated than the orbits of the solar planets. On the whole, to use the words of Sir John Herschel, "we have the same evidence of their rotations about each other that we have of those of Uranus and Saturn about the sun; and the correspondence between their calculated and observed places in such very elongated ellipses must be admitted to carry with it proof of the prevalence of the Newtonian law of gravity in their systems, of the very same nature and cogency as that of the calculated and observed places of comets round the central body of our own."

Having stated the above general facts respecting binary stars, I shall now present to the reader a few telescopic views of these objects.

Fig. 15 represents a telescopic view of *Epsilon* Bootis, with a magnifying power of about 200 times. This is reckoned a very beautiful double star on account of the different colours of the stars of which it is composed, and has an appearance somewhat similar to a planet and its satellite, both shining with innate but differently coloured light. The small star is of a bluish colour, and is separated from the other by a space equal to the diameter of the larger star, and its apparent size is one-third of the other. It is sometimes called *Mirac*, and it is situated about ten degrees north-east of *Arcturus*. The large star has a *reddish* tinge.

Fig. 15

16

17

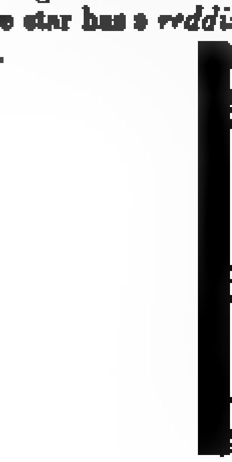


Fig. 16 is a Herculis: the small star is of a bluish colour, separate from the other two diameters of the large star; the blue star is one-third the size of the other. It is situated in the head of Hercules, about thirty degrees south-west from the bright star a Lyræ, and six degrees north-west from *Ras Alhague*, a star of nearly the same magnitude. It comes to the meridian about the middle of July, at nine o'clock in the evening, at an elevation of about fifty-two degrees. This star is also distinguished by the name *Ras Algethi*, and may be seen marked in Plate II., which contains a map of stars which are seen near the meridian about the beginning of September.

Fig. 17 is a view of $\gamma$ Andromedæ: the small star is of a fine greenish-blue colour, separate from the large star about nine seconds, or four diameters of that star; the larger star is of a reddish white. It is situated in the left foot of Andromeda, and is distinguished by the name *Almaack*. It is a star of the second magnitude, about forty-two degrees of north declination, and passes the meridian, in the beginning of December, about half-past ten in the evening, about ten degrees south from the zenith. It is about twelve degrees nearly due west from the variable star *Algol*.

Fig. 18

19

Fig. 18 is *Zeta* Cygni: the smaller star is blue, and they are separated about ten diameters. This star is situated in the eastern wing of the Swan—right ascension, $21^h$ 4′, north declination, twenty-eight degrees, and is about twenty degrees south-east of Denib, the principal star of this constellation.

Fig. 19 represents *Zeta* Aquarii. The two stars are nearly equal in apparent magnitude, and one diameter and a half separate from each other; both stars are of a whitish colour. It is in the middle of three other stars, which together form a figure resembling the letter Y. Its right ascension is $22^h$ 20′, and its south declination about two degrees. It is a star of about the third magnitude, and comes to the meridian at nine o'clock in the evening about the middle of October.

Fig 20 represents the *Pole-star*. The accompanying star is a very faint point, and requires an accurate telescope with considerable power to distinguish it. The large star is white, and the small star somewhat of a ruddy appearance, and is distant from the larger seventeen seconds, or about three or four of its diameters.

Fig. 20

21

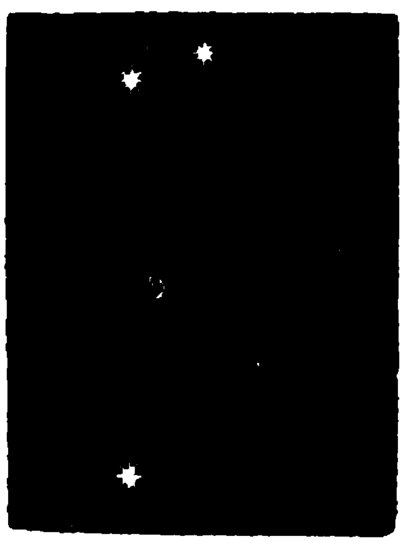
22

Fig. 21 is the double star *Castor*. The smaller star is nearly half the size of the larger, and they are distant about five seconds, or two diameters of the principal star. They are both of a whitish colour. Their situation may be found

on Plate I. Castor and Pollux lie to the north-west of Orion, at a considerable distance from it. They are very conspicuous, are within five degrees of each other, and rise to a very high elevation when passing the meridian, and may be seen throughout the whole winter and spring months. *Castor* is the more elevated of the two.

Fig. 22 represents *Rigel*, a splendid star in the left foot of Orion. The small star is a mere point, and very difficult to be distinguished, and is three or four diameters of the large star from it. The large star is white, the small one of a reddish hue.

Fig. 23

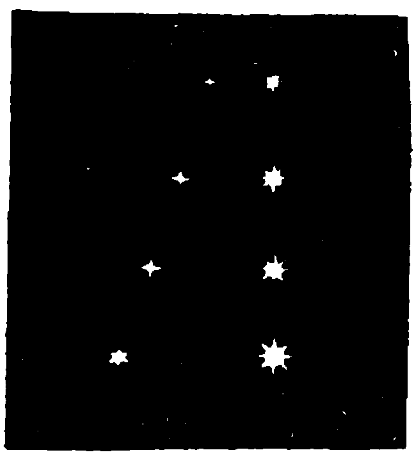


24

Castor. Pollux.

Fig. 23 shows the double star Castor, with a magnifying power of 300. It likewise shows the angular position of the small star at the present time in respect to *Pollux*, (fig 24,) by which it appears that it is nearly at a right angle to a line joining Castor and Pollux, whereas in the time of Dr. Bradley it was *parallel* with a line joining these two stars.

Fig. 25



26

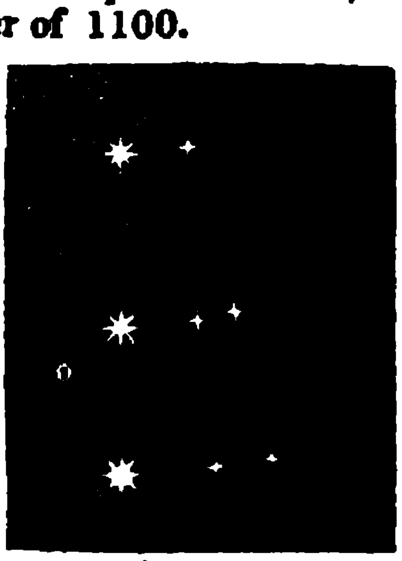
27

28

Bootis.

Fig. 25, 26, 27, and 28, exhibit views of the double star *Epsilon* Bootis, with four magnifying powers. Fig. 25 is its appearance with a power of 227; fig. 26, with a power of 460; fig. 27, with a power of 900; and fig. 28, with a power of 1100.

Fig. 29



30

31

Monoceros.

Fig. 29, 30, and 31, represent telescopic views of the triple star in the left forefoot of the constellation *Monoceros*, or the Unicorn, which forms a very beautiful object in this class of stars. This star appeared at first double, but with some attention, one of the two is discovered to be also double; the first of them is the largest. The colour of these stars is white. With a small power they appear as in fig. 29; with a power of 220, as in fig. 30; and with a power of 450, as in fig. 31. There is a beautiful object of this description, but somewhat different in the configuration of the three stars of which it is composed, to be seen in the tail of the Great Bear; it is the star *Zeta* Ursæ, called also *Mizar*, and is the middle star in the tail.

Such are a few specimens of the telescopic appearances of this class of celestial objects. Some of these objects, in order to be distinctly seen, require telescopes of considerable magnifying power. All the objects, however, referred to above may be seen with a good three feet and a half achromatic telescope, whose object glass is two inches and three quarters aperture. The double star Castor may be seen with powers of 80, 140, and 180. I have frequently distinguished the separation of the two stars with a terrestrial power of only 45; but the higher powers of course are much preferable. In order to perceive the very small star or point of light adjacent to the pole-star, a power of 140 at least is requisite with such a telescope; but it is more distinctly seen with a power of 190 or 200. It is considered as a fair test of the goodness of a telescope of this description when this minute object is perceptible with such powers. The small star connected with *Epsilon* Bootis is likewise an object which requires a considerable degree of magnifying power and distinctness to perceive the separation of the two stars; and it is more difficult to perceive the small star adjacent to *Rigel* than any of these objects

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In the phenomena I have now described, we have a new and interesting scene presented before us, which leads the mind into a train of thought very different from what could have been conceived by astronomers of a former age. To some minds, not accustomed to deep reflection, it may appear a very trivial fact to behold a small and scarcely distinguishable point of light immediately adjacent to a larger star, and to be informed that this lucid point revolves around its larger attendant; but this phenomenon, minute and trivial as it may at first sight appear, proclaims the astonishing fact, that SUNS REVOLVE AROUND SUNS, AND SYSTEMS AROUND SYSTEMS. This is a comparatively new idea, derived from our late sidereal investigations, and forms one of the most sublime conceptions which the modern discoveries of astronomy have imparted. It undoubtedly conveys a very sublime idea, to contemplate such a globe as the planet Jupiter—a body thirteen hundred times larger than the earth—revolving around the sun, at

the rate of twenty-nine thousand miles every hour; and the planet Saturn, with its rings and moons revolving in a similar manner round this central orb in an orbit of five thousand, six hundred and ninety millions of miles in circumference. But how much more august and overpowering the conception of a sun revolving around another sun—of a sun encircled with a retinue of huge planetary bodies, all in rapid motion, revolving round a distant sun, over a circumference a hundred times larger than what has been now stated, and with a velocity perhaps a hundred times greater than that of either Jupiter or Saturn, and carrying all its planets, satellites, comets, or other globes along with it in its swift career! Such a sun, too, may as far exceed these planets in size as our sun transcends in magnitude either this earth or the planet Venus, the bulk of any one of which scarcely amounts to the thirteen-hundred-thousandth part of the solar orb which enlightens our day. The further we advance in our explorations of the distant regions of space, and the more minute and specific our investigations are, the more august and astonishing are the scenes which open to our view, and the more elevated do our conceptions become of the grandeur of that Almighty Being who "marshalled all the starry hosts," and of the *multiplicity* and *variety* of arrangements he has introduced into his vast creation. And this consideration ought to serve as an argument to every rational being, both in a scientific and a religious point of view, to stimulate him to a study of the operations of the Most High, who is "wonderful in counsel and excellent in working," and whose works in every part of his dominions adumbrate the glory of his perfections, and proclaim the depths of his wisdom and the greatness of his power.

In order to form a comprehensive conception and a proper estimate of such binary systems, we have to consider, in the first place, the distances of the stars or *suns* from each other. These distances, in the mean time, cannot be accurately ascertained till something more definite be determined respecting the parallaxes of these bodies. Some have supposed that the distance between some of these binary stars may be as great as the distance between the earth and any of these stars. But such a supposition is highly improbable, if we admit, what is now completely ascertained, that these bodies are intimately connected by the law of gravitation. Their distance, however, must be very great, notwithstanding their apparent nearness to each other, as a few seconds of interval, at the distance of the nearest star, must comprise an immense space. I shall suppose this distance in the case of some of these bodies to be only the one-hundreth part of what is reckoned the distance (namely, twenty billions) of the nearest star. On this supposition, the distance of the revolving star from its primary would be 200,000,000,000, or two hundred thousand millions of miles. The circumference of its orbit would therefore be 1,256,640,000,000 of miles. The small star of $\xi$ Ursæ completes its revolution in fifty-eight years, and consequently, if at the distance now supposed from its primary, must move at the rate of two millions four hundred and seventy-one thousand miles every hour, which is eighty-five times the velocity of the planet Jupiter, and more than twenty-three times the velocity of Mercury in its orbit, which is the swiftest moving planet in our system. This motion would be still more swift in the case of some of the other stars to which we have alluded. The small star of 6 *Eridani*, as determined by Mr. Dunlop, revolves around the larger at the rate of somewhat more than ten and a half degrees per annum, and consequently accomplishes a revolution in little more than thirty years. Its motion, then, at the distance supposed, would be equal to four millions seven hundred thousand miles an hour, which is 162 times the velocity of Jupiter, and about forty-four times that of Mercury. Even the small star of $\gamma$ Leonis, which takes 1200 years to accomplish is revolution, would, on the same supposition, move at the rate of 119,000 miles an hour, which is a greater velocity than that of the swiftest planets of our system. These are immense velocities, especially when we consider the enormous size of the bodies thus impelled; for the least of these suns may be considered as *ten millions* of times larger than the planet Mercury, yet moving with a velocity so much superior.

What, then, would be the velocities of such bodies were we to suppose them as far distant from each other as we are from the nearest star! In the case of *Xi* Ursæ, the velocity would be two hundred and forty-seven millions, one hundred and sixty thousand miles every hour, and four millions, one hundred and fifty thousand every minute; and in the case of 6 *Eridani*, the velocity would be 477,800,000 miles an hour, and 132,735 in a *second*, which is more than sixteen thousand times the velocity of Jupiter. That bodies may move with such velocity is perhaps not impossible, but it is highly improbable that such rapid motions actually exist among bodies of such astonishing magnitudes; and therefore we must suppose that the binary stars are within a moderate distance of each other. Still, that distance must be very considerable, and it is not unlikely may be as great as I have supposed, and if so, it presents

to our view motions more rapid and sublime than any which are known to exist within the limits of our planetary system.

In the next place, we must consider the *system of planets* connected with the binary stars. These stars are evidently suns or self-luminous bodies, otherwise their light would never reach our distant sphere. But we can never admit that suns were created merely to diffuse a useless splendour over the waste spaces of infinity, where there are no sentient beings with visual organs to be cheered with their radiance. In this case they might be said to be created in vain. Hence we must necessarily conclude that these suns are attended with a retinue of planetary bodies, which revolve around them as the centres of light and attractive influence, and we can scarcely conceive a more sublime and astonishing object than that of magnificent suns revolving around still more magnificent and luminous centres, and conveying along with them in their swift career a numerous train of mighty worlds, all in regular and rapid motion around their respective orbs. In such sublime sidereal arrangements we behold a combination of motions and effects of gravitation which are not to be traced throughout any part of the system to which we belong. For while the planets which perform their revolutions around the revolving sun, are affected by the power of attraction from that body, with which they are more immediately connected, they must likewise be attracted by the larger central sun, and their motions sometimes retarded, sometimes accelerated, and variously modified, by its powerful influence, which combined influences must produce a diversity of phenomena and effects unknown in the system of our sun. For the sake of some readers, not accustomed to such views and contemplations, I have given a rude sketch of a binary system in fig. 32, in which the central circles represent the larger sun with its attendant planets, and the other circles the revolving sun and its planets, in four different positions.

Again, in contemplating these binary systems, we perceive a great diversity in the periods of their revolutions. The period of revolution of the small star of ε Bootes is calculated to be not less than 1600 years. An inhabitant of that system would be considered by us an old residenter were he to survive the period of a year, or a single revolution. But in such systems it is not likely that the lapse of duration is marked by so short periods as in our own sublunary abode, nor is it probable that disease and death cut short the existence of its inhabitants, as in the world in which we dwell. Another of these suns takes 1200 years to complete a revolution; another, 629 years; and another, 452; while several others finish their circuits in the comparatively short periods of 55, 43, and even 30 years. Whether these diversities in the periods of revolution be owing to the different magnitudes of the respective bodies, their distances from each other, the amplitudes of the orbits in which they move, or the comparative velocities with which they are carried forward in their career, we have as yet been unable to determine; and a long-continued series of the most delicate and minute investigation is still requisite before such points can be ascertained with any degree of precision. But such striking differences in their periodic revolutions evidently indicate that the characteristic of *variety* is impressed upon all the arrangements connected with those distant systems; which leads us to conclude that there is no system of suns or worlds in the universe exactly resembling another, although they may be all subject to the operation of the same general and fundamental laws. From such circumstances we are likewise led to infer that among bodies in the more distant regions of creation there may be motions and arrangements altogether different from any thing we yet know, which produce scenes of beauty, sublimity, and grandeur, far surpassing what the mind of man can yet conceive.

In regard to the *number* of such binary systems, no precise estimate has yet been made. We have, however, every reason to believe that their number is very great. I have already stated that about 6000 double stars have been detected by M. Struve, the two Herschels, Mr. Dunlop, and Sir James South. On the doctrine of chances, it is in the highest degree improbable that the greater part, or even any considerable number of these bodies, appear double by their accidental proximity, or being so placed one behind another as to be nearly in the same line of vision. We may therefore conclude that at least 4000 of these stars are binary systems connected by the law of mutual gravitation. Between forty and fifty of these bodies have been ascertained beyond doubt to form revolving systems, and time must be allowed for further investigations. It is but lately that the attention of astronomers has been directed to such observations; and on account of the very minute distances of the revolving stars from each other, and the slight variation of the angle of position which can be traced for a series of years, an age or two is requisite in order to determine with precision the degree or progress of their revolutionary movements. Some of their orbits, too, may be so extensive, or their motions so comparatively slow, that several thousands of

years may elapse before the periods of some of these bodies be completed; and if so, we have no reason to conclude that they are *not* binary systems, although half a century should elapse without any change being perceived in their angular positions. In the course of fifty or sixty years hence, we have reason to believe many important discoveries will be made in reference to the bodies in question, and what is at present doubtful or obscure will be rendered definite and precise. In the mean time, we may safely take for granted that several thousands of those revolving suns and systems lie within the range of our telescopes, whose revolutions will ere long be determined. But as our most powerful instruments can carry us only a very small way, comparatively, beyond the outward boundaries of those mighty heavens which surround us, ten thousands of such systems may exist in those remoter regions, which will for ever remain inexplorable by mortals.

There is another interesting view which may be taken of these binary systems, and that is—*the contrast of colours which some of the stars composing these systems exhibit.* I have already alluded to some of these stars being of different colours, and any observer who is possessed of a good telescope may easily satisfy himself on this point. "Many of the double stars," says Sir *J.* Herschel, "exhibit the beautiful and curious phenomena of contrasted or complementary colours. In such instances, the larger star is usually of a ruddy or orange hue, while the smaller one appears blue or green; probably in virtue of that general law of optics which provides that when the retina is under the influence of excitement by any bright-coloured light, feebler lights, when seen alone would produce no sensation but of whiteness, shall for the time appear coloured with the tint complementary to that of the brighter. Thus a yellow colour predominating in the light of the brighter star, that of the less bright one in the same field of view will appear blue; while if the tint of the brighter star verge to crimson, that of the other will exhibit a tendency to green, or even appear as a vivid green under favourable circumstances. The former contrast is beautifully exhibited by *Iota Cancri*, the latter by *Gamma* Andromedæ, both fine double stars. If, however, the coloured star be much the less bright of the two, it will not materially affect the other. Thus, for instance, *Eta* Cassiopeiæ exhibits the beautiful combination of a large white star and a small one of a rich ruddy purple. It is by no means, however, intended to say that in all such cases one of the colours is a mere effect of contrast; and it may be easier suggested in words than conceived in imagination, what variety of illumination *two suns*, a red and a green, or a yellow and a blue one, must afford a planet circulating about either; and what charming contrasts and 'grateful vicissitudes'—a red and a green day, for instance, alternating with a white one and with darkness—might arise from the presence or absence of one or other, or both, above the horizon. Insulated stars of a red colour, almost as deep as that of blood, occur in many parts of the heavens, but no green or blue star (of any decided hue) has, we believe, ever been noticed unassociated with a companion brighter than itself."

The fact of *coloured suns*, of suns belonging to the same system diffusing light of opposite or contrasted colours, presents a novel and interesting idea, and a splendid scene, in which a lively imagination may luxuriate while depicting the diversity of aspects under which objects will appear in those worlds which are alternately illuminated by such a variety of irradiation. It is somewhat difficult, however, to form a distinct conception of the particular beauties, sublimities, and contrasts, which will be produced by such admirable arrangements. We are unacquainted with the nature and qualities of the substances which are thus illuminated, and therefore cannot determine the peculiar hues or splendour which will result from the reflection of such irradiations; but we may easily conceive there will be a considerable difference in the variety and splendour of such illuminations, and in the contrast of colours which will be exhibited when the revolving planets are in different parts of their orbits. When in such positions as *A, B, C, D,* (fig. 32,) they will be more directly under the influence of both

Fig. 32.

suns than when at *E* and *F*, and of course the effect of the contrasted coloured rays will

be most remarkable. One hemisphere of a planet may be illuminated with a yellow sun, while the other is at the same time enlightened by a green, and both suns may occasionally shine in the same hemisphere, producing such a blending of hues, and a contrast of colouring over the whole landscape, as to render the aspect of the scene completely different at one time from what it is at another. In different parts of the planets' courses around their primary suns these effects will be variously modified, so as to produce an almost perpetual variety in the scenery of such worlds. A sun of a brilliant white colour may perhaps be seen rising, while a sun of a ruby hue is descending below the horizon, and when both suns are absent, the starry firmament will appear in all its splendour, and every object around present a contrast to its previous appearance.

The science of optics, and particularly the experiments which have been made on *polarized light*, shew us what a variety of combinations of vivid and beautiful colours may be produced by certain modifications of light, which may easily lead us to conceive of the sublime and diversified brilliancy of colouring which must be the result of the irradiation of suns of different hues. The light of the stars in general is greatly diversified, although on a cursory view of the firmament they appear nearly of the same aspect. The rays of *Sirius*, for example, are not only strikingly different from those of *Aldebaran*, but from those of many other stars which seem to bear a nearer resemblance. In tropical climates, where the sky is clearer than with us, and almost of a dark ebony colour, the different hues of the stars are more striking and perceptible to the naked eye than when seen through our comparatively hazy atmosphere. In this respect then, as well as in several others, the declaration of the inspired writer is literally true, that "one star differeth from another star in glory." Milton, in the eighth book of his "Paradise Lost," utters a sentiment on this subject which seems to be almost prophetic, when he represents Raphael in his address to Adam as saying—

> "Other suns, perhaps,
> With their attendant moons thou wilt descry,
> *Communicating male and female light*,
> Which two great sexes animate the world,
> Stored in each orb, perhaps, with some that live."

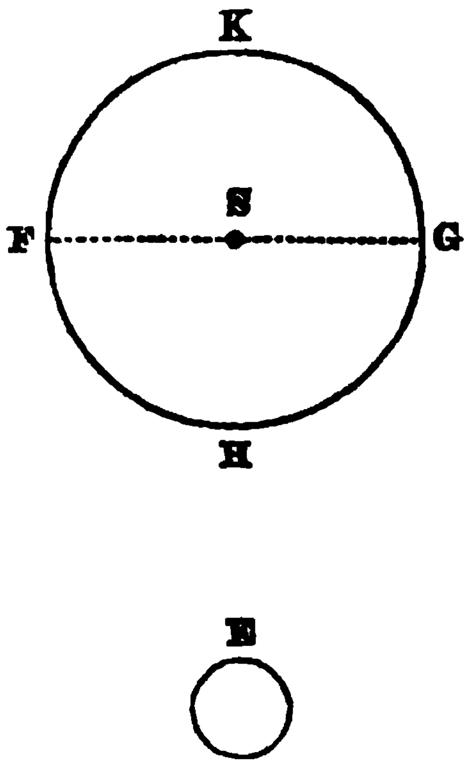
In these phenomena we have another proof of the infinite *variety* which the Creator has introduced into the systems of the universe—a variety in regard to *colour* as well as to magnitude, motion and other arrangements,—which leads us to conclude that although we were permitted to make the tour of universal nature, we should meet with no worlds, or systems of worlds, in which the scenery and arrangements are exactly the same, but that each would display its own peculiar harmonies, beauties, and sublimities, and the enraptured spectator, at every stage of his excursion, would behold a new manifestation of "the manifold wisdom of God."

It would be an important and interesting acquisition in astronomy could we determine exactly, or even to a near approximation, the *distances* of any of these binary systems, and the *actual dimensions* of the orbits of the revolving stars. It appears from what has been formerly stated, (pp. 37, 38,) that the parallax, and consequently the distance, of 61 *Cygni* has been determined by Professor Bessel. Now this is a double star, or binary system, and one of the stars is found to have an annual angular motion of about two-thirds of a degree; from which it is inferred that the period of its revolution may be about 540 years, and that the semi-major axis of its orbit is seen under an angle of more than 15″. Were these and other correlative points accurately settled, we might soon determine to a near approximation the extent of its orbit, the space through which it moves in the course of a revolution, and consequently its rate of velocity; but as the motion of revolution of this star is so extremely slow, a considerable period of years may elapse till all the elements of its orbit be accurately ascertained.

A few years ago, a method was pointed out by M. Savory, a French astronomer, by which the dimensions of the orbit of a revolving star might be determined. This method depends upon the fact that light moves with a certain known rate of velocity. Suppose that one of the double stars moves round another in an orbit which is nearly parallel to our line of vision, it is evident that the one half of its orbit will be nearer to us than the other, and that at the most distant point of its course the star will be removed from us to a distance equal, or nearly equal, to the whole diameter of its orbit further than when at the point which is nearest the earth. As the light which proceeds from the star takes a certain time in moving across the interval which separates us from that body before it reach our eye, we must necessarily see the star in a point of its orbit different from that in which it is actually placed. Let $S$ (fig. 33) represent the central star, $E$ the earth, and $H\ F\ K\ G$ the orbit of the revolving star. When the star is at $H$, it is nearest the earth; and when at $K$, it is farther distant by the whole diameter of its orbit. Now, when the star proceeds from $H$, the nearest point of its orbit, its light will take a longer period to reach the earth in proportion as it moves on in its course from $H$ to $G$ and from $G$ to $K$, and consequently will appear

to take a longer time than in reality it does in moving along that portion of its orbit; but in returning through the other half of its orbit, *R F H*, it will appear to pass through it in a less space of time than it actually does, since the light which proceeds from it takes less and less time to reach our eye as it approaches in its course towards *F* and *H*. If, therefore, we could accurately determine the difference of time between these two half revolutions of the star, we should have *data* sufficient for determining, to a near approximation, the dimensions of the orbit in miles, or other known measures; and having found these dimensions, the distance of the star from the earth could likewise be found by an easy trigonometrical calculation.

Fig. 33.




This method of finding the dimensions of binary systems is entitled to the praise of ingenuity; but it will be difficult, in many instances, to put it in practice. Its accuracy will depend upon our knowing the *position* of the orbit with regard to our eye, and our ascertaining exactly when the star is in *H* or at *K*, or the two opposite points of its orbit. Besides, a very long time must intervene before observations of this kind can be completed, since most of the periods that have been determined in regard to double stars extend to several hundreds of years, and the shortest period yet known of any of these revolving bodies is above thirty years. It is generally taken for granted, by those who have adverted to this subject, that the distance between the revolving and the central star is as great, or nearly as great, as that which intervenes between us and the nearest star; and hence, in their illustrations of this point, they have supposed light to take at least one year in crossing the orbit of a revolving star, which of course would make the diameter of such an orbit above *six billions* of miles. But there appears no reason for forming such extravagant suppositions, as in such a case the binary stars could scarcely be supposed to have any intimate connexion. We might almost as soon suppose that the star Sirius might revolve around our sun, or the sun around Sirius. It is not likely that the double stars in general are much further from each other than the distance I formerly supposed,—namely, 200,000,000,000, and consequently the diameter of their orbits about 400,000,000,000 of miles.—Through this space light would pass in the course of 24 days and 2⅔ hours; and therefore it would require very accurate determinations indeed of the points *H* and *K*, or the nearest and remotest points of the orbits, before any precise conclusions could be deduced, if the stars be not farther distant than I have supposed, and it is perhaps as probable that they are considerably within that distance. It is not improbable, however, that the dimensions of the orbits of some of those stars whose periods are shortest may in this way be determined; but a considerable period must elapse before the requisite operations can be made.

## CHAPTER IX.

### *On Treble, Quadruple, and Multiple Stars.*

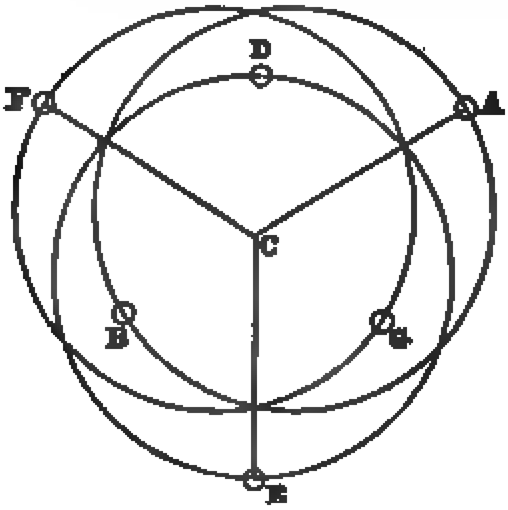
Besides the combinations of double stars described in the preceding chapter, treble, quadruple and multiple stars have been discovered, many of which appear to be ultimately connected, and to be formed into regular systems, whose motions and phenomena must of course be more diversified and complicated than those of binary systems. Without entering into particular discussions on this subject, I shall present to the reader only two or three general remarks, with a short list of some of the treble and multiple stars to which I allude.

The more profound and minute our investigations are into the scenery of the heavens, the more do we discover of the endlessly diversified modes by which the system of universal nature is arranged and conducted, and the more clearly do we perceive a display of the infinite wisdom and intelligence of its almighty Author. Who could have previously conceived of one sun and system revolving round another, had not recent observations demonstrated the astonishing fact! As one discovery naturally leads to another, so the facts which have already been ascertained may lead to discoveries in future generations still more wonderful and sublime than those which have hitherto been brought to light. The discovery of binary systems leads

to the conclusion that almost all the close groups or clustering stars, visible to the naked eye or descried by telescopes, are multiple systems, or suns and planetary worlds linked together by a universal law or principle, acting in different modes, and producing an immense variety of physical phenomena and effects. Guided by principles and facts recently brought to light, astronomers have only to direct their attention more particularly to such objects, to watch with care the slightest movements in the sidereal heavens, and take their measurements of distances and angular positions with the utmost precision; and then we may expect that succeeding generations will have unfolded to their view a more sublime and comprehensive prospect of the arrangements of the universe.

In certain cases it has already been ascertained that treble stars form one connected system. The star marked ζ Cancri is a treble star of this description. Two of the stars are considerably unequal; the largest of these is larger than the single star, and the least of the two is less than the single star. The first and second largest, as described by Sir W. Herschel, are pretty unequal, and the second and third pretty unequal. The nearest are pale red. They require very favourable circumstances to be distinctly seen; they are just separated by a power of 227, and with 460 their distance is ¼ the diameter of the smaller one. This is considered a case in which three suns revolve around a common centre. Observation has not yet afforded a sufficient data for determining the particular motions or arrangements of such complex systems; but we may conceive them as arranged in a manner somewhat similar to what we have delineated in fig. 34, where the point $C$ may represent the common centre of gravity

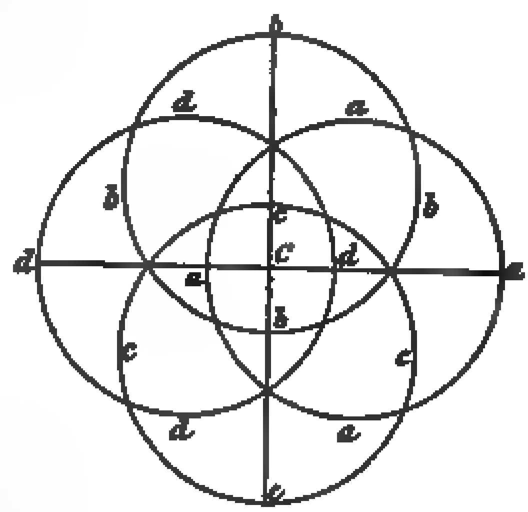
Fig. 34.




around which the three bodies revolve. The circles $A\ B$, $D\ E$, $F\ G$, represent the orbits of the revolving bodies, which may be conceived as lying in different planes oblique to each other, to prevent any occasional collision or too near an approach.

A *quadruple* system may be represented by fig. 35, where $C$ is the centre of gravity round which the four bodies revolve, and the circles $a\ a\ a\ a$, $b\ b\ b\ b$, &c., the respective orbits in which they move. The star ε Lyræ is probably a system of this kind. It is a star of the fifth magnitude, situated about two degrees north-east from the bright star *Vega*, or α Lyræ. The stars of which it is composed are easily distinguishable by a telescope of moderate power, and it is easily found from its vicinity to the very bright star adja-

Fig. 35.



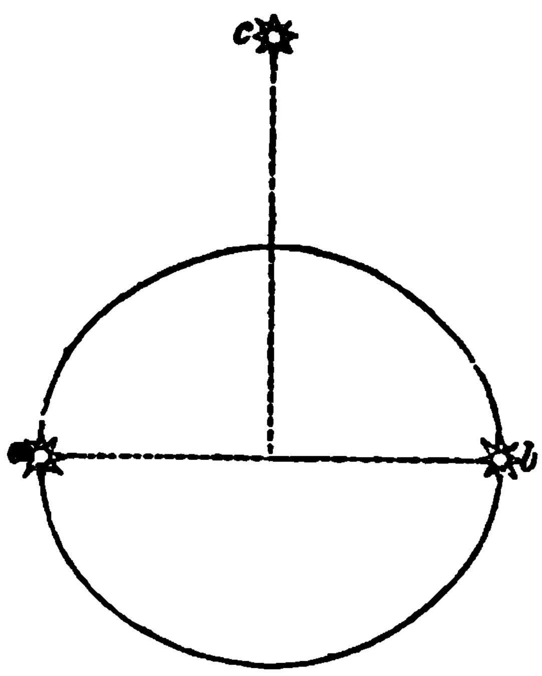

cent to it. The small stars of which it is composed are situated nearly as represented in fig. 36. We might conceive of such a system of bodies revolving in a still more complex manner,—the star $V$ revolving round $S$, the star $U$ revolving round $T$, the system of $V$ and $S$ revolving round a point $a$, and the system of $U$ and $T$ round the same point or centre in a separate but more expansive orbit. But it is difficult to form diagrams of such complex systems.

Fig. 36.

There are many different combinations by which we may conceive treble, quadruple, and multiple stars to revolve round their common centre of gravity, which it would be too tedious to describe, particularly as such motions have not yet been accurately ascertained. Sir W. Herschel describes one of these possible combinations which is not a little singular. Suppose two equal stars, a

and *b*, (fig. 37,) moving in a circular orbit round their common centre of gravity which will be the centre of the circle. From the centre of the circle, draw a line perpendicular to the plane of their orbit, extending to equal distances above and below this centre. Let us now suppose a third star, *c*, to fall from one extremity of this perpendicular, from a state of rest; it will obviously descend with a gradually accelerated motion till it reaches the centre of gravity; and passing onwards with a motion gradually retarded, it will move to the other end of the perpendicular, where it will arrive at a state of rest, and again return and continue to oscillate between these two points. The two stars which move in a circular orbit may describe equal ellipses of any degree of eccentricity. In this case, however, the perturbations will affect not only the planes of their orbits, but also their figures; and the length of the oscillations of the third will be sometimes increased and diminished.

Fig. 37.




A sun oscillating in a line perpendicular to the orbit of other two suns, and continuing its motion for ages in that line, is certainly a very strange idea; and yet, from the variety we perceive in the arrangements of the universe, it is not at all improbable that such combinations may exist among treble stars. The idea here intended to be conveyed may be illustrated by suspending a ring, and placing a wire perpendicular to it in its centre. The ring will represent the plane of the orbit in which the two equal stars move, and the perpendicular wire the line or course of the third star moving backward and forward with different degrees of accelerated and retarded motion. The motions connected with quintuple and multiple stars must be still more complex than those to which we have adverted; but it is difficult in the mean time to form any distinct ideas on the subject, till actual observation in the course of succeeding ages shall pave the way for deducing definite conclusions. The discoveries already made open to view new scenes of celestial mechanism, and new views of the diversified and admirable contrivances of Divine Wisdom, so that, in reference to such objects, we may apply to the almighty architect the language of the sacred writer—"How unsearchable are thine operations and thy ways past finding out!" When we consider that around each of these moving suns a retinue of planets must be supposed to wheel their courses, at different distances and in different periods of time, we cannot but feel astonished at the *complexity* of motions, perturbations, and other effects which must necessarily follow; yet we are bound to believe that every thing moves onward, not only without confusion, but in the most perfect order and harmony, for He who at first arranged the plan of the material world, and impressed upon matter the laws which now operate, is possessed of boundless intelligence, and foresees at one glance all the effects which those laws can possibly produce; and, so far as our observation extends, every object and movement in nature appears to be adjusted with the most perfect regularity.

The solution of the "problem of three bodies" was considered as a work of so great nicety and difficulty that none but such profound mathematicians as Clairaut, D'Alembert, and Euler, could undertake such a delicate and laborious investigation. This problem was, "to determine the curves described by three bodies projected from three points given in position, and with velocities given in quantity and direction—the force with which they gravitate being directly as their quantities of matter, and inversely as the squares of their distance." If the resolution of such a problem required so great acuteness of intellect, and so eminent skill in the science of analysis, what perspicacity of intellect, and what profound knowledge of every thing connected with physical and mathematical investigations must be requisite to determine the courses described and the perturbations produced by the complex motions of five, six, or seven suns all connected together, yet moving in different curves and in different directions, along with hundreds of planets, each connected with its own sun and pursuing its own distinct course, yet acted upon in succession with different degrees of force by the attractive influence of other suns! All our boasted powers of analysis are completely incompetent for such determinations. The faculties of an archangel, or of intelligences of a higher order than that of man, are alone adequate to such investigations; and this circumstance affords a presumptive evidence that such superior intelligences actually exist in the universe, and that man, in the present improvement of his powers, may be in the act of training for the employments and the society of such intellectual beings in a future scene of existence.

The following brief list of treble and multiple stars, selected chiefly from Sir W. Herschel's catalogue, is given for the sake of those who may be disposed to inspect them with their telescopes.*

*π*, or 42 *Aries, in the ham*, sixth magnitude.—The three stars, which are all in a line, are excessively unequal; the largest is white, and the two smallest are mere points. With a power of 460, the two nearest are 1½ diameter of the largest star. The third is about 25″ from the largest.

*ε*, or 4 or 5 *Libra*.—This is a remarkable double-double star—or a double star, each star itself being a double star. The first set consists of stars that are considerably unequal. The largest is very white, and the smallest reddish. Their distance with 227 is one diameter of the larger one; the second set are white and equal, the preceding being rather the largest; their distance 1½ diameter of either. The star appears of the fourth magnitude.

*σ, or* 48 *Orion*, a star of the fourth magnitude, *a little below the lowest of the three stars in the belt*. This is a double-treble star, or two sets of treble stars, almost similarly situated. The two nearest of the preceding set are equal; the third larger, and pretty unequal when compared with the latter two. With a power of 222, the distance of the two nearest is 2 diameters of either. The two nearest of the following set are very unequal. The largest of the two and the farthest are considerably unequal, the largest being white and the smallest bluish. With a power of 222, their distance is about 2½ diameters of the largest. The distance of the two farthest is 43″ Right ascension, 5h 30′; south declination, 2° 43′.

*θ, or* 41 *Orion, the small telescopic trapezium in the nebula*. Right ascension, 5h 26′; south dec., 5° 32′. The stars composing this quadruple star are considerably unequal. The most southern star of the following side of the trapezium is the largest; and the star in the opposite corner is the smallest, the other two being nearly equal. The largest is pale red; the star preceding the largest inclined to garnet; and the star opposite the largest dusky. Distance of the two stars in the preceding side, 8¾ seconds; in the southern side, 12¾ seconds; in the following side, 15 seconds; and in the northern side, 20 seconds. The first star (in right ascension) is of the seventh magnitude, the second of the eighth magnitude, the third of the fifth magnitude, and the fourth of the sixth or seventh magnitude. M. Struve found the angles of position, in 1819, to be as follows—

| 3d and 4th: | 1st and 3d: |
|---|---|
| 29° 45′ north following. | 45° 9′ north preceding. |

| 1st and 2d: | 2d and 4th: | 2d and 3d: |
|---|---|---|
| 58° 8′ north fol. | 31° 0′ north pre. | 74° 0′ north pre. |

44 *Orion preceding the two ι's, or below* 1, 2, *θ—of the third or fourth magnitude*. The preceding set of this double-triple star consists of three equal stars, forming a triangle, and are all dusky. The distance of the two nearest with a power of 227 is about 3 diam. The following set consists of three stars of different sizes, forming a circle. The middle star is the largest; the one to the south is pretty large; and the third is very small. The two largest are white, and the smallest pale red. Distance 36¼″. These stars are east by north from the bright star *Rigel*, at the distance of about 5°.

12 *Lynx, below the eye; about* 18° *or* 19° *north-east of Capella and* 16° *north of* β *Auriga*. The two nearest of this curious treble star are pretty unequal. The larger is white, and the smaller white inclining to a rose colour. With a power of 227 their distance is ½ the diameter of the smaller one. The first and third are considerably unequal; the second and third pretty unequal; the colour of the third being pale red, and its distance from the first 9″.

*ξ, or* 51 *Libra; of the fourth or fifth magnitude*. This star appears at first double, but the larger of the two will be found to consist of two stars. They are nearly unequal, and both white. With a power of 460 their distance is ¼ the diameter of the larger.

¾° *south of* 58 *Auriga, in a line parallel to β and θ, south-east of the bright star Capella*. This is a cluster of stars containing a double star of the second class and one of the third. The two of the second are very unequal, and both red. Their distance with 460 is 2½ diameters of the larger. Those of the third class are equal, and both red. Distance, 17″. Above 20 stars are in view with a power of 227.

*A large star* 1° *preceding ζ towards* 41 *of the Swan*. The two nearest are extremely unequal. The largest is white, and the smallest pale red. Their distance with 460 is 2½ diameters of the largest. The third and the largest are extremely unequal, and belong to the fifth or sixth class.

*South preceding* 27 *Swan, the middle of three, the most southern of which is the* 27. This star is quadruple and sextuple. In the quadruple of north preceding set, the two nearest are very unequal. Their distance with 678 is 11″. The two largest are almost

* As the following and similar lists are inserted for the purpose of reference to amateur observers, the general reader, if he think proper, may pass over such lists and descriptions.

equal, and both red. Distance, 29½″. In the sextuple or south following set, the two largest are pretty unequal, and both red. Their distance is 19″.—The other stars are as small as the smallest of the quadruple set.

*¾° north preceding* H *Gemini,* (of the fifth magnitude,) *in a line parallel to the* 65 *Orion,* (in the club, and of the fifth magnitude,) *and ζ Taurus, the middle of the three.* The stars in this quintuple star are in the form of a cross. The two nearest, or the preceding of the five, are extremely unequal. Distance 20½″. There is a very obscure star of the third class near the last of the three, in the obscure star of the cross. Other five stars are dispersed about the quintuple one.

*Between β and ζ Dolphin, but nearer to β.* All the three stars are whitish red, and nearly equal. Distance of the two nearest with a power of 278, 21½″.

*Near* 27 *Cepheus, near δ.* The distance of the two nearest of this treble star is about 20″.

*β, or* 10 *Lyra,* (of the third magnitude, and about 7° south-east of the bright star Vega.) The stars of this quadruple star are all white, the second, third, and fourth, inclining to red. The first and second are considerably unequal; the first and third very unequal; and the first and fourth unequal. Distance of the first and second, 44″.

*β, or* 78 *Gemini,* (Pollux.) The stars of this multiple star are extremely unequal. The nearest distance is 1′ 57″; the next distance is 3′ 17″.

*In the Unicorn's head.* This multiple star consists of one star with about twelve around it. 16° west of Procyon.

*ζ, or* 16 *Cancer.* This very minute treble star requires very favourable circumstances to be distinctly seen. The two stars of which the preceding one consists are considerably unequal. The largest of these is larger than the single star, and the least of the two is less than the single star. The first and second largest and pretty unequal, and the second and third pretty unequal. The two nearest are pale red. They are just separated with a power of 278, and with 460 their distance is ¼ the diameter of the smaller one. *Zeta* Cancri is situated about 12 or 13 degrees south-east of Pollux, nearly in a line parallel to that which joins Castor and Pollux, and nearly the same distance north by east from Procyon. It appears as a star of the fifth or sixth magnitude, and is sometimes distinguished by the name *Tegmine.* As a double star it is easily distinguished by a power of 140, with a 3½ feet achromatic telescope, whose aperture is 2¾ inches, and might perhaps be seen with a power of 100. But it requires a much higher power to distinguish it as a treble star.

Most of the above stars may be found by consulting large planispheres of the heavens, or a common celestial globe. To facilitate the finding out of their positions, I have inserted in the above list some special directions, which may perhaps be of use to the astronomical tyro who is furnished with a moderately good telescope. It is to be regretted that, even on some of our latest 18-inch celestial globes, several of the stars above referred to are not distinctly marked, either with their number or with the Greek letters by which they are generally distinguished, and some of them are altogether omitted; such, for instance, as the celebrated star 61 *Cygni,* which is a double star, and whose proper motion is greater than that of any other star yet discovered in the heavens.

## CHAPTER X

### *On the Milky Way.*

As we advance in our survey of the distant regions of the universe, the astonishing grandeur and extent of the sidereal heavens gradually opens to our view. We have hitherto considered only a few objects on the outskirts of the heavens, in respect to their distance, magnitude, and the wonderful complication of systematic motions which prevails among them. Had we no other objects to engage our attention, ages might be spent in contemplating and admiring the economy and magnificence of those starry groups which appear to the unaided eye on the nearer boundary of our firmament. But all this is visible to man's unassisted vision is as nothing when compared with the immensity of august and splendid objects which stretch themselves in boundless perspective towards infinity. The discoveries of modern astronomy have enlarged the sphere of our conceptions far beyond what could formerly have been surmised, and opened to view a universe boundless as its Creator, where human imagination is lost and confounded, and in which man appears like a mere microscopic animalculum, and his whole habitation as a particle of vapour when compared to the ocean. In contemplating the visible firmament with the unassisted eye, we behold only the mere portals, as it were, which lead to the interior recesses of the vast

Temple of Creation. When we direct our views beyond these outer portals, by means of the most powerful telescopes, we obtain a view of some of its more magnificent porches, and a faint glimpse of those splendid apartments which we shall never be able to explore, but which lead us to form the most august conceptions of the extent and grandeur of what is concealed from our view. In entering this Temple "not made with hands," the splendour of its decorations, the amplitude of its scale, and the awfulness of infinitude, forcibly strike the imagination. There is sufficient to awaken into exercise all the powers and feelings of devotion, and to excite us to fall down into humility and adoration before Him whose word spoke into existence this astonishing fabric, and "whose kingdom ruleth over all." These reflections may not appear altogether unappropriate when entering on a description of the *Milky Way*, which contains objects calculated to excite our highest admiration.

When we take a general view of the heavens about the months of August, September, and October, and during the winter months, we cannot fail observing a large, irregular, whitish zone stretching across the sky, with a few interruptions, from one end of the firmament to another. This mighty zone, thus stretching itself around us, is sometimes termed the *galaxy*, sometimes the *Via Lactea*, but more frequently, in plain English, the *Milky Way*, from its resemblance to the whiteness of milk. This luminous band is visible to every observer, and is the only real and sensible circle in the heavens. When traced throughout its different directions, it is found to encircle the whole sphere of the heavens, though in some parts of its course it is broader and more brilliant than in others. It forms nearly a *great circle* of the sphere, but it coincides neither with our equator, ecliptic, nor colures, nor with any other artificial circles which we conceive as drawn around the firmament. In all ages, so far as we know, this wonderful zone has retained the same position among the constellations as at the present day, and is frequently alluded to both by the astronomers and the poets of antiquity. Thus Ovid, on account of its lustre, represents it as the high road to heaven, or the court of Jupiter:

> "A way there is in heaven's extended plain,
> Which when the skies are clear as seen below,
> And mortals by the name of *Milky* know;
> The groundwork is of stars, through which the [road
> Lies open to the Thunderer's abode."

And Milton, in his "Paradise Lost," alludes to it in these lines:

> "A broad and ample road, whose dust is gold,
> And pavement stars, as stars to us appear;
> Seen in the galaxy that Milky Way,
> Like to a circling zone powdered with stars."

This zone may be traced in the heavens as follows:—Beginning near the northern quarter of the heavens, at the head of Cepheus, or about 30° from the north pole, we may trace it through Cassiopeia, Perseus, Auriga, part of Orion, and the feet of Gemini. At this last point it crosses the Zodiac, and proceeding southward across the equinoctial into the southern hemisphere, it passes through the Unicorn and the middle of the ship Argo, where it is most luminous. It then passes through Charles's Oak, the feet of the Centaur, the Cross, the Altar, the tail of Scorpio, the bow of Sagittarius, and a part of Ophiuchus. Here it separates into two branches as it passes again over the Zodiac into the northern hemisphere. One branch runs through the tail of Scorpio, the bow of Sagittarius, the shield of Sobieski, the feet of Antinous, Aquila, Delphinus, the Arrow, and the Swan. The other branch passes through the upper part of the tail of Scorpio, the side of Serpentarius, Taurus Poniatowski, the Goose, and the neck of the Swan, where it again unites with the other branch, and passes on to the head of Cepheus, the place of its beginning. After sending off the two branches above mentioned, they unite again after remaining separate for the space of more than 100 degrees. There is another small separation of the Milky Stream between Cassiopeia and Perseus. The two streams appear to leave a blank about the head of Perseus, and a considerable space on each side of it, to the extent of about thirty degrees in length, and three in breadth, and are again joined into one stream in the sword of Perseus, adjacent to Cassiopeia.*

From the above description it will appear that the form, breadth, and general appearance of this zone are various in different parts of its circuit round the heavens. In some places it appears dense and luminous, in others faint and scattered; in certain points it appears broad, and in others narrow. Its breadth in some places, as between Auriga and Perseus, is only about four or five degrees; in other places, as in the southern parts of Scorpio, Ara, and the Cross, its breadth is from ten to fifteen or eighteen degrees. It assumes the appearance of a double path from the tail of the Scorpion, through the bow of Sagittarius, Antinous, Aquila, Taurus Poniatowski, the Goose, and part of the Swan. It is more or less visible at every season of the year; but in Britain and in other northern latitudes it is most conspicuous during the months of August, September, and October, the latter part of July, and the beginning of November. About the middle of August, at nine o'clock in the evening, it may be seen stretching in an

* See the direction of this zone in the map of the stars on Mercator's projection.

oblique direction over the heavens, from north-east to south-west, and its apparent motion along the heavens may be traced along with that of the other constellations. At other seasons of the year, and at other hours of the night, its position and form will appear somewhat different. It appears most brilliant in the southern hemisphere, particularly in the neighbourhood of Argo, Ara, and the splendid constellation of the Cross. Between the tropics, where the atmosphere is clear and serene, it appears most vivid and brilliant. Mr. Brydon informs us that, from the top of Etna, it appeared "like a pure flame that shot across the heavens."

The ancients seem to have conjectured that the whiteness of this zone was owing to a confluence of stars; for Ovid, in the lines above quoted, says, "Its groundwork is of stars." Soon after the invention of the telescope this conjecture was confirmed, and astronomers were astonished at the number of stars which appeared in this bright zone of the heavens; and their number appeared to be increased in proportion to the magnifying powers of their telescopes. But it was not before Sir W. Herschel applied his powerful instruments to this region of the heavens that its profundites were explored, and all its minute nebulous parts shown to consist of countless myraids of stars, of every apparent magnitude, stretching onward to the regions of infinity, till they appeared to be lost to the view, even when assisted by the largest telescopes. On first presenting telescopes of considerable power to this splendid zone, we are lost in amazement at the number, the variety, and the beautiful configurations of the stars of which it is composed. In certain parts of it every slight motion of the telescope presents new groups and new configurations, and the new and wondrous scene is continued over a space of many degrees in succession. In several fields of view, occupying a space not much more than twice the breadth of the moon, you perceive more of these twinkling luminaries than all the stars visible to the naked eye throughout the whole canopy of heaven. You seem to penetrate, as it were, to the remoter bounderies of creation, and feel bewildered and lost amidst the immensity of the universe. I have never been inspired with higher ideas of grandeur and sublimity, nor felt deeper emotions of humility and reverence, than when occasionally contemplating this stupendous scene through telescopes of considerable brilliancy and power. There is not another scene in creation, open to the view of mortals, calculated to fill the soul with more august conceptions, or to inspire it with more profound admiration and awe. In such surveys we behold "new heavens" and other firmaments rising to view, whose distances baffle the utmost stretch of imagination.

"O what a confluence of ethereal fire
From suns unnumbered down the steep of heaven
Streams to a point and centres on my sight."

The following contains a brief summary of Sir W. Herschel's observations on this region of the heavens, made with a Newtonian reflecting telescope of twenty feet focal length and an aperture of eighteen inches. He found that this instrument completely resolved all the whitish appearances into stars, which the telescopes he formerly used had not light enough to do. The portion he first observed was that about the hand and club of Orion, and he found in this space an astonishing number of stars, whose number he endeavoured to estimate by counting many *fields*; that is, the apparent space in the heavens he could see at once through his telescope, and computing from a mean of these how many may be contained in a given portion of the milky way. In the most vacant place to be met with in that neighbourhood he found 63 stars; other six fields contained 110, 60, 70, 90, 70, and 74 stars, a mean of all which gave 79 for the number of stars to each field; and then he found that, by allowing fifteen minutes for the diameter of his field of view, a belt of fifteen degrees long and two broad, which he had often seen pass through his telescope in an hour's time, could not contain less than 50,000 stars, large enough to be distinctly numbered; besides which he suspected twice as many more, which could be seen only now and then, by faint glimpses, for want of sufficient light. The reader may acquire some conceptions of this immense number of stars occupying so small a space, if he consider that it is fifty times more than all the stars which the naked eye can discern at one time throughout the whole heavens, and that the space they occupy is only the $\frac{1}{1375}$th part of the visible canopy of the heavens; so that if every part of the firmament were equally rich in stars, there would be within the reach of such a telescope as Herschel's no less than 68,750,000, or sixty-eight millions, seven hundred and fifty thousand stars. And we are further to consider that it was only in the comparatively "vacant places" of this zone that the number of stars above stated were perceived.

In some of his observations of other parts of this zone, Sir W. Herschel informs us that he descried a much greater number of these luminaries in a similar extent of space. "In the most crowded parts of the Milky Way," he says, "I have had fields of view that contained no fewer than 588 stars, and these

were continued for many minutes, so that in one quarter of an hour's time there passed no less than 116,000 stars through the field of view of my telescope." In order to appreciate this description, we are to suppose the telescope to have been fixed in one position at the time of observation, and that by the diurnal motion of the earth, or the apparent motion of the heavens, the first field of stars was gradually carried out of view, and other fields appeared in succession, till, in the space of fifteen minutes of time one hundred and sixteen thousand stars passed over the field of vision. Now, the field of view taken in by the telescope was only 15′ of a degree, a space which is less than the *one-fourth* part of the apparent size of the moon. In this narrow field were seen about as many stars as are generally beheld throughout the whole sky by the naked eye in a clear winter's night; for although nearly a thousand stars might be seen by a very acute eye in a clear atmosphere, yet there are few persons that in our climate could distinctly recognize above 600 or 700 stars even in a clear night. At another time, this indefatigable astronomer perceived no less than two hundred and fifty-eight thousand stars pass before his view in the course of forty-one minutes. In the space between $\beta$ and $\gamma$ of the Swan, the stars are found clustering, with a kind of division between them, so that they may be considered as clustering towards two different regions. In this space, taking an average breadth of about five degrees of it, he found from observation that it contains more than 331,000 stars, which gives above one hundred and sixty-five thousand for each clustering collection.

Supposing the Milky Way to be, on an average, twelve degrees broad, the whole of it will contain an area of 4320 degrees = 12 × 360. Now, if the space examined by Herschel between *Beta* and *Gamma* of the Swan be about fourteen degrees in length and five degrees in breadth, it will contain an area of seventy degrees, which is somewhat less than the $\frac{1}{61}$st part of the space occupied by the Milky Way. Were we to suppose every part of this zone equally rich in stars as the space now referred to, it will contain no less than 20,191,000 stars, or more than twenty thousand times the number of those which are visible to the naked eye. The whole visible heavens, considered as a spherical plane, contains an area of 41,253 degrees. Now, could we suppose every portion of the firmament to be equally well replenished with stars as the milky zone, there would be more than 195,000,000* of stars in the heavens discernible by such a telescope as Herschel's; but as there are comparatively few other regions of the heavens so densely crowded with stars as the Milky Way, we must make a certain abatement from this estimate, though it is probable there are more than one hundred millions of stars within the reach of our best instruments were all the spaces of our firmament thoroughly explored; and future generations, with more powerful telescopes, may add indefinitely to the number. Had we taken the most crowded field of stars which Herschel perceived through his telescope (namely, 588) as our standard for estimating their number, the amount of stars in the Milky Way would have been forty millions, and in the whole heavens, 388 millions. In short, to use the words of Sir John Herschel—"This remarkable belt, when examined through powerful telescopes, is found (wonderful to relate!) *to consist entirely of stars scattered by millions*, like glittering dust, on the black ground of the general heavens."

In regard to the *distances* of some of these stars, we may easily conceive that they are immense, and consequently far removed from our distinct comprehension. Sir W. Herschel, in endeavouring to determine a "*sounding line*," as he calls it, to fathom the depth of the stratum of stars in the Milky Way, endeavours to prove, by pretty conclusive reasoning, that his twenty feet telescope penetrated to a distance in the profundity of space not less than 497 times the distance of Sirius; so that a stratum of stars amounting to 497 in thickness, each of them as far distant beyond another as the star Sirius is distant from our sun, was within the reach of his vision when looking through that telescope. Now, the least distance at which we can conceive Sirius to be from the earth or the sun is 20,000,000,000,000, or twenty billions of miles; and consequently the most distant stars visible in his telescope must be four hundred and ninety-seven times this distance, that is, 9,940,000,000,000,000, or nearly ten thousand *billions* of miles! Of such immense distance it is evident we can form nothing approaching to a distinct conception. We can only approximate to a rude and imperfect idea by estimating the time in which the swiftest bodies in nature would move over such vast spaces. Light, which is endowed with the swiftest degree of motion yet known, and which flies at the rate of nearly twelve millions of miles every minute, would require one thousand six hundred and forty years before it could traverse the mighty interval stated above; and a cannon ball, flying at the rate of 500 miles an hour, would occupy more than 2,267,855,068, or two thousand, two hundred and sixty-seven millions, eight hundred thousand years, in passing through the

* $\frac{41253}{70} = 589\frac{23}{70} \times 331{,}000 = 195{,}067{,}757$.

same space!—a period of years before which all the duration that has passed since man was placed on this globe appears only like a few fleeting hours, or "as an handbreadth or a span."*

Here, then, let us pause for a moment, and consider the august spectacle presented to view. We behold a few whitish spaces in the firmament, almost overlooked by a common observer when he casts a rude glance upon the evening sky; yet in this apparently irregular belt, which appears only like an accidental tinge on the face of the firmament, we discover, by optical instruments, what appears to be an amazing and boundless universe. We behold not only ten thousands, but *millions* of splendid suns, where not a single orb can be perceived by the unassisted eye. The distance at which these luminous globes are placed from our abode is altogether overwhelming; even the most lively imagination drops its wing when attempting its flight into such unfathomable regions. The scenes of grandeur and magnificence connected with such august objects are utterly overwhelming to such frail and limited beings as man, and perhaps even more exalted orders of intelligences may find it difficult to form even an approximate idea of objects so distant, so numerous, and so sublime.

On our first excursions into the celestial regions we are almost frightened at the idea of the distance of such a body as Saturn, which a cannon ball projected from the earth, and flying with its utmost velocity, would not reach in 180 years. We are astonished at the size of such a planet as Jupiter, which could contain within its circumference more than a thousand globes as large as the earth. We are justly amazed at the stupendous magnitude of the sun, which is a thousand times the size of Jupiter, and which illuminates with its splendour a sphere of more than five thousand millions of miles in circumference. But what are all such distances and dimensions, vast and amazing as they are, compared with the astonishing grandeur of the scene before us? They sink into comparative insignificance, and are almost lost sight of amidst the myriads of splendid suns which occupy the profundities of the Milky Way. What is *one* sun and *one* planetary system in the presence of *ten millions* of suns perhaps far more resplendent, and of a hundred times this number of spacious worlds which doubtless revolve around them? Yet this scene, stupendous as it is, is not the universe. It is perhaps, as we shall see, only a comparatively small corner of creation, which beings at an immensely greater distance will behold as an obscure and scarcely discernible speck on the outskirts of their firmament; so that amidst this vast assemblage of material existence we may say, in the language of the inspired prophet, when speaking of the Almighty, that *even here* is but "the hiding of his power." What then must the whole of creation be? and what must be the ineffable splendour and majesty of Him who laid the plan of the mighty fabric, whose breath kindled so many millions of suns, whose hands set in motion so many myriads of rolling worlds, who supports them in their ample and diversified courses, and whose moral government extends over all? And what is man, and the globe on which he dwells, amidst this scene of immensity and magnificence?—an atom in the infinity of space—a particle of vapour compared to the ocean—a being who, in respect to the magnificence of creation and the grandeur of his Creator, is "as nothing, and is counted to him as less than nothing and vanity."

Yet, amidst all the magnificence of this vast system of universal nature, man is not forgotten by his Maker; his hand supports him, his wisdom guides him, and his overflowing goodness provides, in a thousand different modes, for his happiness and enjoyment. He shares of the Divine beneficence and care in common with all the bright intelligences that people the amplitudes of creation, and is as amply provided for as if the Almighty had no other world under his superintendence. Within the moral government of the Creator of the universe he may rest secure and confident that he is not overlooked amidst the im-

* The celebrated Schroeter, of Lilienthal, was a frequent observer of the stars which crowd the Milky Way. He was in the habit of observing with one of the largest reflecting telescopes to be found in Europe. This telescope was one of the finest ever constructed, and was the workmanship of Professor Schrader, of Kiel. The diameter of the speculum was about nineteen inches; it was about two inches in thickness, and towards the edge cast conical, so that the diameter of the polished surface is almost a quarter of an inch less than at the back, which circumstance was considered of the greatest utility in the finishing and polishing. It had a focus of twenty-six feet, and, without the frame, weighed eighty pounds. The large octangular tube was constructed with boards, made impenetrable to rain; and the instrument when ready for use was twenty-seven feet long. An immense quantity of apparatus and machinery was requisite for steadying and moving it. The figure of the speculum was so perfect, that it could bear a power of 800 or 1000 times without diminishing the aperture. Its capability of resolving the nebulosity of the Milky Way seems to have equalled that of the telescopes of Herschel. He allowed twenty degrees of its length from α Cygni to pass through the field, and the sight drew from him the natural exclamation, "What Omnipotence!" The power on the telescope in such observations was 179, and the diameter of the field, fifteen minutes; and the number of stars it contained at once could never be counted. They were never estimated at less than fifty or sixty, and often reached or exceeded 150. He calculated that the number of stars visible through this telescope could not be less than 12,000,000.

mensity of being, for his presence pervades the infinity of space, and his knowledge extends to the minutest movements of all his creatures. Under his paternal care, not only man, but the crawling worm, the fluttering insect, the little ant, and even the microscopic animalculum, find a home and provisions, as well as the highest order of his creatures; for "he openeth his hand and supplieth the wants of every living being."

Notwithstanding the size of the Milky Way, and the immense number of stars of which it is composed, it is now considered as nothing more than *one of the nebulæ*, or starry systems, which appears to be dispersed throughout the universe. It is supposed, and with some reason, that it is the nebula, or assemblage of stars, in which our sun is placed. Its situation in this nebula is reckoned to be, not in the centre of its thickness, but rather towards one of the sides, near the point where it diverges into two branches. According to this hypothesis, the Milky Way is to be considered as the projection of the nebula upon the concave surface of the sky, as seen from a point within it. "We gather this," says Sir W. Herschel, "from the appearance of the galaxy, which seems to encompass the whole heavens, as it certainly must do if the sun is within the same; for suppose a number of stars arranged between two parallel planes indefinitely extended every way, but at a given considerable distance from one another, and calling this a sidereal stratum, an eye placed somewhere within it will see all the stars in the direction of the planes of the stratum projected into a great circle, which will appear lucid on account of the accumulation of the stars, while the rest of the heavens at the sides will only seem to be scattered over with constellations, more or less crowded, according to the distance of the planes or number of stars contained in the thickness or sides of the stratum."

Fig. 38.

Thus if the solar system be supposed at *S*, in the middle of the nebula *a b e d e f*, with two branches, *a c*, *b c*, (fig. 38,) the nebula will be projected into a circle *A B C D*, the arches *A B C*, *A E C*, being the projection of the branches *a c*, *b c*, while the stars near the sides of the stratum will be seen scattered over the remaining part of the heavens among the spaces *F*, *I*, *H*, *K*, *G*. If the eye were placed somewhere without the stratum, at no very great distance, the appearance of the stars within it would assume the form of one of the lesser circles of the sphere, which would be more or less contracted according to the distance of the eye; and if this distance were exceedingly increased, the whole stratum might at last be drawn together into a lucid spot of any shape, according to the position, length, and height of the stratum.

In order to determine those points, Sir W. Herschel put in practice a method which he calls *gauging the heavens*, which consists in repeatedly counting the number of stars in the fields of view very near each

other, by which he obtained a mean of the number of stars in that part of the heavens. He then proceeds on the supposition that the stars are equally scattered, and from the number of stars in any part of the heavens he deduces the length of his visual ray, or the distance through which his telescope had penetrated, or, in other words, the distance of the remotest stars in that particular region of the heavens. To illustrate this, let us suppose the Milky Way a nebula, and that the sun is not placed in its centre. Then, on the supposition that the stars are nearly equally scattered, it is evident that the part of the Milky Way where the stars are the most numerous extend furthest from the sun, and the parts where they are less numerous must extend to a less distance. Proceeding on these grounds, Sir W. Herschel found the length of his visual ray for different parts of the heavens. In some cases he found it equal to 497 times the distance of Sirius, supposed to be the nearest star, as formerly stated. The following is a representation of a section of the nebula of the Milky Way, according to his delineation. This section is one which makes an angle of thirty-five degrees with our equator, crossing it in 124½ and 304½ degrees. A celestial globe adjusted to the latitude of fifty-five degrees north, and having *o Ceti* near the meridian, will have the plane of this section pointed out by the horizon. If the solar system (fig. 39) be at *S*, the brightness of the Milky Way will be greatest in the directions *S a*, *S b*, *S p*, where the stars that intervene are most numerous, or where the visual ray is longest. In the lateral directions *S n*, *S m*, the nebulosity will not appear from the small number of interposing stars, and the stars, though numerous, will appear more scattered. In the direction *S c*, on account of the opening between *a* and *b*, there will be an empty space contained between these two branches where the nebulosity is not observed, as is the case in the Milky Zone between $\mu$ Scorpio in the south and $\gamma$ Cygni in the north, a length of about 102 degrees. The stars in the border, which are marked larger than the rest, are those pointed out by the gauges; the intermediate parts are filled up by smaller stars arranged in straight lines between the gauged ones. The circle around *S* represents an extent about forty times the distance of the nearest fixed stars, which may be considered as comprehending all those which are visible to the naked eye.

"From this figure," says Sir W. Herschel, "we may see that our nebula is a very extensive branching, compound congeries of *many millions of stars*, which most probably owes its origin to many remarkably large, as well as pretty closely scattered small stars that may have drawn together the rest." Again—"If it were possible to distinguish between

Fig. 39.

the parts of an indefinitely extended whole, the nebula we inhabit might be said to be one that has fewer marks of antiquity than any of the rest. To explain this idea more clearly, we should recollect that the condensation of clusters of stars has been ascribed to a gradual approach; and whoever reflects on the number of ages that must have passed before some of the clusters that are to be found in my intended catalogue could be so far condensed as we find them at present, will not wonder if I ascribe a certain air of youth and vigour to very many regularly scattered regions of our side-

real stratum. There are, moreover, many places in it in which, if we may judge from some appearances, there is the greatest reason to believe that the stars are drawing towards secondary centres, and will in time separate into clusters so as to occasion many subdivisions. Our system, after numbers of ages, may very possibly become divided so as to give rise to a stratum of two or three hundred nebulæ; for it would not be difficult to point out so many beginning or gathering clusters in it. This throws considerable light upon that remarkable collection of many hundreds of nebulæ which are to be seen in what I have called the *nebulous stratum* in Coma Berenices. It appears from the branching and extended figure of our nebulæ, that there is room for the decomposed small nebulæ of a large reduced former great one to approach nearer to us in the sides than in any other parts." . . . . "Some parts of our system seem indeed already to have sustained greater ravages of time than others; for instance, in the body of the Scorpion is an opening, or hole, which is probably owing to this cause. It is at least four degrees broad, but its height I have not yet ascertained. It is remarkable that the 80th nebula of the *Connoissance des Temps*, which is one of the richest and most compressed clusters of small stars I remember to have seen, is situated just on the west border of it, and would almost authorize a suspicion that the stars of which it is composed were collected from that place, and had left the vacancy."

The remarks in the above paragraph I present to the reader merely as the opinions of an illustrious astronomer and an indefatigable observer of celestial phenomena, without vouching for the accuracy or probability of such speculations and hypotheses. To determine the reality of such changes in bodies so numerous and so distant, would require an indefinite lapse of ages; yea, perhaps the revolutions of eternity are alone sufficient for determining the sublime movements and changes which happen among the immense assemblages of material existence which constitute the universe. There is a high degree of probability that every thing within the material system is liable to change of one kind or other, and that there is no sun nor world, among all the myriads of globes which replenish the sidereal heavens, but what is *actually in motion*,—and moving, too, with a velocity which the inhabitants of such a world as ours can scarcely appreciate; and such motions, in the course of ages, may be productive of a vast diversity of scenery in different regions of the universe. And if so, it presents to view another instance of that *variety* which the Creator has introduced into his universal kingdom to gratify the unbounded desires of intelligent beings.

I shall conclude this chapter with the following description of the Milky Way, which Sir John Herschel has published since his residence in the southern hemisphere:—"The general aspect of the southern circumpolar region—including in that expression sixty or seventy degrees of south-polar distance—is in a high degree rich and magnificent, owing to the superior brilliancy and larger developement of the Milky Way, which from the constellation of Orion to that of Antinous is in a blaze of light, strangely interrupted, however, with almost starless patches, especially in Scorpio, near α Centauri, and the Cross; while to the north it fades away pale and dim, and is in comparison hardly traceable. I think it is impossible to view this splendid zone, with the astonishingly rich and evenly distributed fringe of stars of the third and fourth magnitudes—which form a broad skirt to its southern border, like a vast curtain—without an impression amounting almost to a conviction, that the Milky Way is not a mere stratum, but an *annulus*; or at least that our system is placed within one of the poorer or almost vacant parts of its general mass, and that eccentrically, so as to be nearer to the parts about the Cross than to that diametrically opposed to it."

## CHAPTER XI.

### *On Groups and Clusters of Stars.*

On a cursory view of the heavens, the stars appear to be very irregularly scattered over the concave of the firmament. In some places a considerable interval appears between neighbouring stars, while in others they appear so crowded that the eye can with difficulty perceive the spaces between them. Even to the unassisted eye, there are certain groups of this description which strike the attention of every observer, and lead to the conclusion that the stars of which they are composed have been brought together by some general law, and not by mere casual distribution. Of these, the group called the *Pleiades*, or Seven Stars, is the most obvious to common observers. This group is situated in the constellation Taurus, about 14° to the westward of the star Aldebaran (*see* Plate I.,) and may be seen.

every clear evening from the end of August till the middle of April.* It is generally reckoned that only *six* stars can be distinctly counted in this group by common eyes, but that originally they consisted of *seven*, which every one could easily perceive, and it has therefore been conjectured that one of them has long since disappeared. To this circumstance Ovid, who lived in the time of our Saviour, alludes in these lines:

"Now rise the *Pleiades*, those nymphs so fair
Once seven numbered, now but six there are."†

In fabulous history it is said that the Pleiades the star Merope, one of the Atlantides, appears more dim and obscure than the rest, or is altogether extinquished, because as the poets fancy, she married a mortal, while her sisters married some of the gods or their descendants. Dr. Long, however, declares that he himself had more than once seen seven stars in this group; and a learned astronomical friend assured him that he had seen eight stars among the Pleiades, where common eyes can discover but six; and Kepler says of his tutor Mæstlinus, that "he could reckon fourteen stars in the Pleiades without any glasses." This difference in the number seen by different persons in this group is obviously owing to the different degrees of acuteness of vision possessed by the respective individuals. However small the number perceived by the naked eye, the telescope shows them to be a pretty numerous assemblage. Dr. Hook, formerly professor of geometry in Gresham College, informs us that, directing his twelve-feet telescope (which could magnify only about seventy times) to the Pleiades, he did in that small compass count seventy-eight stars; and making use of longer and more perfect telescopes, he discovered a great many more of different magnitudes.

The ingenious Mr. Mitchell, more than fifty years ago, started the idea of the stars being formed into groups or systems which are entirely detached from one another, and have no immediate connexion. In reference to the Pleiades, he conducted his reasoning as follows:—"The Pleiades are composed of six remarkable stars, which are placed in the midst of a number of others that are all between the third and sixth magnitudes; and comparing this number six with the whole number visible in the heavens to the naked eye, he calculated, by the doctrine of chances that among all this number, if they had been dispersed arbitrarily through the celestial vault, it was about five hundred millions to one that six of them should be placed together in so small a space. It is therefore so many chances to one that this distribution was the result of design, or that there is a reason or cause for such an assemblage."

The constellation called *Coma Berenices* is another group, more diffused than the Pleiades, which consists chiefly of small stars which can scarcely be distinguished in the presence of the moon. This beautiful cluster lies about five degrees east of the equinoctial colure, and midway between the star *Cor Caroli* on the north-east, and Denebola, in the Lion's tail, on the south-west. If a straight line be drawn from *Benetnasch*—the star at the extremity of the tail of the Great Bear—through Cor Caroli, and produced to Denebola, it will pass through this cluster. It may also be distinguished as situated about twenty-six degrees west by north from the bright star *Arcturus*. The confused lustre of this assemblage of small stars bears a certain resemblance to that of the Milky Way, and, besides the stars of which it is chiefly composed, it contains a number of nebulæ. Sir W. Herschel supposes that the stratum of nebulæ in this quarter runs out a very considerable way, and that it may even make the circuit of the heavens, though not in one of the great circles of the sphere. He also supposes that the situation of the stratum is nearly at right angles with the great sidereal stratum in which the sun is placed, that the Coma itself is one of the clusters in it, and that it is on account of its nearness that it appears to be so scattered. He apprehends that the direction of it towards the north lies probably, with some windings, through the Great Bear onwards to Cassiopeia, thence through the girdle of Andromeda and the Northern Fish, proceeding towards Cetus; while towards the south it passes through the Virgin, probably on to the tail of Hydra and Centaurus.

Another group, somewhat similar, but less definite, is found in the constellation of Cancer; it is called *Præsepe*, or the Bee Hive, and is a nebulous cluster of very minute stars, not separately distinguishable by the naked eye. A telescope of very moderate power, however, easily resolves it into small stars. It is sufficiently luminous to be seen as a nebulous speck by the unassisted eye, and is somewhat like the nucleus of a comet, for which it has frequently been mistaken by ordinary observers. It is situated in a triangular position with regard to Castor and Procyon, or the Little Dog. A line drawn from Procyon in a north-easterly direction meets with Præsepe at the distance of twenty degrees. This line, drawn in a north-westerly direction from Præsepe, meets Castor at the same distance These lines form nearly a right angle, the angular point being in Præsepe. It may

* A telescopic view of the Pleiades is exhibited in the Appendix.

† "Quæ septem dici, sex tamen esse solent."

otherwise be discovered by means of two stars of the fourth magnitude lying one on either side of it at the distance of about two degrees. It may likewise be found by conceiving a line drawn through Castor and Pollux to the south-east, and continued about fifteen degrees, or three times the distance between Castor and Pollux. This cluster, Sir W. Herschel thinks, belongs to a certain nebulous stratum so placed as to lie nearest us. This stratum runs from $\epsilon$ Cancri towards the south, over the 67th nebula of the *Connoissance des Temps*, which is a very beautiful and much compressed cluster of stars, easily to be seen by any good telescope, and in which he has observed above 200 stars at once in the field of view of his great reflector, with a power of 157. This cluster appearing so plainly with any good common telescope, and being so near to the one which may be seen with the naked eye, denotes it to be probably the next in distance to that within the quartile formed by $\gamma$ $\delta$ $\eta$ $\theta$. From the 67th nebula, the stratum of Cancer proceeds towards the head of Hydra.

I have seldom contemplated a more brilliant and beautiful view in the heavens than one of the fields of view of this cluster of stars. With a 3½ feet achromatic, and a power of 95, I have counted from fifty to seventy stars. Fifteen or twenty of the most brilliant of these presented beautiful configurations: one of them was an equilateral triangle; another, an isoscelus; a third, nearly of the figure of a cone; a fourth, parallel lines, &c. In more than two instances, three brilliant equi-distant stars appeared in a straight line, similar to the belt of Orion, while a considerable number of the remaining stars appeared extremely small. With a 6½ feet achromatic, whose objec' glass is 4 inches diameter, and a power of 110, this view was rendered still more brilliant. Several fields of view, nearly of this description, may be perceived in this cluster. Fig. 40 represents one of these views, in which some of the smaller stars are omitted. This view was taken with the 3½ feet telescope, having an erect eye-piece. The configurations appear somewhat different in their relations to each other when viewed with an inverting eye-piece.

Another cluster is found in the sword-handle of *Perseus*, which is crowded with stars of a smaller size than in the clusters already noticed, and which requires a telescope of greater power to resolve them and show them separated from each other. Perseus is one of the northern circumpolar constellations, nearly opposite to the three stars in the tail of the Great Bear. A line drawn from these stars through the Pole-star meets the sword and head of Perseus at nearly an equal distance on the opposite side. It is directly north of the Pleiades, between Andromeda and Auriga. The sword is in the neighbourhood of Cassiopeia. A line drawn from *Algenib*, the brightest star in this constellation, to the middle of Cassiopeia, passes through the sword-handle where the cluster is situated, which is about midway between those two objects.

If the lowermost of the three small stars which form the *sword* of Orion be viewed with a good telescope, a beautiful configuration of stars will be perceived. Fig. 41* represents the principal stars comprehended in one field of view at this point, as taken with a six feet and a half telescope, with an inverting eye-piece, magnifying 110 times; it exhibits a distant resemblance of the whole constellation of Orion as seen by the naked eye. But in the neighbourhood of certain

Fig. 40.

Fig. 41.*

parts of the Milky Way, particularly about the regions in the vicinity of the star *Altair* and in the constellation Cassiopeia, the stars, though smaller, are much more numerous. With a very moderate power on the above mentioned telescope, I have had fields of view of from fifty to a hundred stars, some of them beautifully arranged, and such fields continued over a space of several degrees.

The above may be considered as specimens of groups of stars, which every one possessed of telescopes may easily examine for himself. They form very beautiful objects for exhibiting to young people and to amateurs in astronomy; and it cannot but strike the mind with wonder and admiration to behold, in one point of view, within a space little more than that of the *one-fifth* of the apparent size of the moon, nearly a hundred resplendent suns emitting their effulgence from regions immeasurably distant, and arranged in beautiful symmetry and order—a scene of creating power surpassing in grandeur ten thousand worlds such as ours, and in which our whole planetary system would appear only as the smallest twinkling star. Such telescopic views of the nocturnal heavens have a tendency to expand the capacity of the soul, to inspire it with magnificent conceptions, and to raise its affections above the low ambition and paltry concerns of this transitory scene to the distant and more magnificent scenes of the Divine empire. To the devout and contemplative philosopher the following lines of the poet may be applied:

> "Not to this evanescent speck of earth
> Poorly confined—the radiant tracks on high
> Are his exalted range; intent to gaze
> Creation through, and from that full complex
> Of never-ending wonders to conceive
> Of the sole Being right, who spoke the word,
> And Nature moved complete."
>
> THOMSON's *Summer*.

Sir W. Herschel makes a distinction between *groups* and *clusters* of stars. A group is a collection of stars closely and almost equally compressed, and of any figure or outline. There is no particular condensation of the stars to indicate the existence of a central force, and the groups are sufficiently separated from neighbouring stars to show that they form peculiar systems of their own. According to this definition, the congeries of stars I have pointed out above are to be considered as belonging to the class of *groups*. *Clusters* of stars differ from groups in their beautiful and artificial arrangement. Their form is generally round, and their condensation is such as to produce a mottled lustre somewhat resembling a nucleus. The whole appearance of a cluster indicates the existence of a central force, residing either in a body or in the centre of gravity of the whole system. The stars of which it is composed appear more and more accumulated towards the centre.

Many such clusters are found in the heavens invisible to the naked eye, and whose existence as dim specks of light can only be recognized by the assistance of optical instruments. Telescopes of moderate power exhibit them only as small round or oval specks, somewhat resembling comets without tails; but when these objects are examined with telescopes of great power, "they are then," as Sir John Herschel remarks, "for the most part, perceived to consist entirely of stars crowded together so as to occupy almost a definite outline, and to run up to a blaze of light in the centre, where their condensation is usually the greatest." "Many of them, indeed, are of an exactly round figure, and convey the complete idea of a globular space filled full of stars, insulated in the heavens, and constituting in itself a family or society apart from the rest, and subject to its own internal laws. It would be a vain task to attempt to count the stars in one of these *globular clusters*. They are not to be reckoned by hundreds; and on a rough calculation, grounded on the apparent intervals between them at the borders (where they are seen not projected on each other) and the angular diameter of the whole group, it would appear that many clusters of this description must contain at least ten or twenty thousand stars, compacted and wedged together in a round space, whose angular diameter does not exceed eight or ten minutes—that is to say, in an area not more than a tenth part of that covered by the moon." The stars composing such clusters appear to form a system of a peculiar and definite character. "Their round figure clearly indicates the existence of some general bond of union in the nature of an attractive force, and in many of them there is an evident acceleration in the rate of condensation as we approach the centre, which is not referable to a merely uniform distribution of equidistant stars through a globular space, but marks an intrinsic *density* in their state of aggregation, greater at the centre than at the surface of the mass."

Let the reader pause for a moment on the object now described, and consider the glimpse it affords us of the immensity of the universe, and of the innumerable globes of light with which it is replenished. A point in the firmament, scarcely perceptible to the unassisted eye, which a common telescope shows only as a small dim round speck, yet is found by powerful instruments to consist entirely of stars to the number of *ten or twenty thousand!* And at what a distance must such a cluster be when its stars appear to be blended and projected one upon another, hundreds of them

appearing only like a lucid point! and yet the distance between any two of them is perhaps ten thousand times greater than that of Saturn from our globe. From such a region even light itself must take many thousands of years ere it can reach our world.' In this almost invisible point, which not one out of fifty thousand, or even one out of a million of earth's inhabitants has yet perceived, what a scene of grandeur and beneficence may be displayed; and what a confluence of suns, and systems, and worlds and intelligences of various orders, may exist, displaying the power and wisdom and goodness of the great Father of all! Every circumstance connected with such an object shows that its distance must be immeasurably great, and consequently the luminaries of which it is composed immense in magnitude. But suns of such size and splendour cannot be supposed to be thrown together at random through the regions of infinity, without any ultimate design worthy of the Creator, or without relation to the enjoyments of intelligent existence; and therefore we may reasonably conclude that ten thousand times ten thousands, and myriads of myriads of exalted intelligences exist in that far distant region, compared with the number of which all the inhabitants of our globe are but "as the drop of a bucket, or as the small dust of the balance."

In short, in this dim and almost imperceptible speck we have concentrated a confluence of suns and worlds, at least ten times surpassing in size and splendour the sun, moon, and planets, and all the stars visible to the naked eye throughout all the spaces of our firmament! What then must be the number and magnitude of all the other clusters which the telescope has brought to view? what the number of those which lie beyond the limits of human vision in the unexplorable regions of immensity? and what must the UNIVERSE itself be, of which all those numerous starry systems are but an inconsiderable part? Here the human faculties are completely lost amidst the immensity of matter, magnitude, motion, and intelligent existence, and we can only exclaim, "Great and marvellous are thy works, Lord God Almighty!"

Figure 41 represents a view of one of the clusters alluded to above, as seen in the twenty-feet reflector at Slough. Sir J. Herschel, who has given a delineation of it in his "Treatise on Astronomy," says "it represents some-what rudely, the thirteenth nebula of Messier's list, described by him as *nebuleuse sans etoiles*." Its right ascension is $16^h\ 36'$; and its north declination, $36°\ 46'$; by which its place may easily be found on a celestial globe. It is situated on the constellation Hercules, between the stars $\eta$ and $\zeta$. These stars are of the third magnitude, and lie north and south of each other, at the distance of seven degrees and a third; they come to the meridian about the middle of July, at nine o'clock in the evening, but of course may be seen at many other periods of the year, particularly in the spring and autumn. The star $\eta$ lies about twenty-two degrees nearly due west from the bright star *Vega* or $\alpha$ Lyræ. In the map of the stars on Plate II. it is marked with the letter *a*, and the star $\zeta$ below it with the letter *b*. The cluster is somewhat nearer to $\eta$, or the upper star, than to the other. It is just perceptible to the naked eye, and with a telescope of small power, such as a common "night and day telescope," it appears like a small round comet.

The following is a list of the places of six of the principal clusters of this description, which may be considered as specimens of these remarkable objects:

1. Right ascension, $15^h\ 10'$; north declination, $2°\ 44'$. This cluster lies about eight degrees south-west from *Unuk*, the principal star in the Serpent, and comes to the meridian, about the middle of June, at nine o'clock in the evening.

2. Right ascension, $13^h\ 34'$; north declination, $39°\ 15'$; between the tail of Chara and the thigh of Bootes, about twelve degrees north-west of Arcturus, nearly on a line between that star and *Cor Caroli*, but nearer Arcturus.

3. Right ascension, $13^h\ 5'$; north declination, $19°\ 5'$; in Coma Berenices, fourteen degrees west by south of Arcturus. A line drawn from Arcturus through $\eta$ Bootes meets this cluster at somewhat more than double the distance of these two stars.

4. Right ascension, $17^h\ 29'$; south declination, $3°\ 8'$; between the stars $\gamma$ and $\mu$ of Serpentarius, but nearer to the latter.

5. Right ascension, $21^h\ 25'$; south declination, $1°\ 34'$; in Aquarius, about 2 degrees north of $\eta$ in the west shoulder, nearly in a line with $\epsilon$ *Pegasi* or *Enif*.

6. Right ascension, $21^h\ 22'$; north declination, $11°\ 26'$. This cluster lies north from No. 5, at the distance of thirteen degrees, and about three or four degrees north-west of the star *Enif*, or $\epsilon$ Pegasi.

Such are a few specimens of *compressed* clusters of stars. Sir. W. Herschel has given a catalogue of more than a hundred of such clusters dispersed over different parts of the heavens, many of which require powerful telescopes to resolve them into stars. These clusters may be considered as so many distinct *firmaments*, distributed throughout the spaces of immensity, each of them comprising within itself an assemblage of stars far more numerous than what appears to the vulgar

eye throughout the whole face of our nocturnal sky. To those intelligences that reside near the centre of such clusters, the stars connected with their own cluster or system will be those which they will chiefly behold in their sky; and in those clusters which are of a globular form, the stars will appear nearly equally dispersed over the face of their firmament. In those starry assemblages which show a great compression about the centre, an immense number of stars of the first magnitude will decorate their sky, and render it far more resplendent than that with which we are surrounded—another instance of that *variety* which distinguishes all the scenes of creation. Scarcely any other star will be visible except those which belong to their own system. If the magnificent system of stars with which our sun is connected be at all visible, it will only appear like a dim and inconsiderable speck in the remote regions of immensity, or as a small cluster or nebula, such as those we perceive with difficulty through our telescopes. Such are the grand, the diversified, and wonderful plans of the Creator throughout his vast and boundless universe.

# CHAPTER XII.

## *On the Different Orders of the Nebulæ.*

### Section I.

### *General Remarks on the Subject of Nebulæ.*

The further we proceed in our researches into the sidereal heavens, the scene of Creating Power and Wisdom becomes more expansive and magnificent. At every step of our progress the prospect enlarges far beyond what we had previously conceived; the multitude and variety of its objects are indefinitely increased; new suns and new firmaments open to view on every hand, overwhelming the mind with astonishment and wonder at the immensity of Creation, and leaving it no room to doubt that, after all its excursions, it has arrived only at "the frontiers of the Great Jehovah's kingdom." Wherever we turn our eyes amid those higher regions, infinity appears to stretch before us on either hand, and countless assemblages of the most resplendent objects are every where found diversifyng the tracts of immensity. To investigate such objects in relation to their number, magnitude, motion, and the laws by which they are united and directed in their movements, completely baffles the mathematician's skill, and sets all his hitherto acquired powers of analysis at defiance, and demonstrates that we are still in the infancy of knowledge and of being. Here, all finite measures fail us in attempting to scan such amazing objects, and to penetrate into such unfathomable recesses; length, breadth, depth, and height, and time and space, are lost. We are justly filled with admiration at the amazing grandeur of the Milky Way, where suns and worlds are counted by MILLIONS. When exploring its dimensions and sounding its profundities, we seem to have got a view of a universe far more expansive than what we had previously conceived to be the extent of the whole creation. But what shall we say if this vast assemblage of stars systems be found to be no more than sing[le] *nebula*, of which several thousands, perha[ps] even richer in stars, have already been di[s]covered! and that it bears no more proportio[n] to the whole of the sidereal heavens aroun[d] us, than a small dusky speck which our tele[s]copes enable us to descry! Yet such is th[e] conclusion which we are led to deduce fro[m] the discoveries which have been lately mad[e] respecting the different orders of the nebul[æ] of which I shall now proceed to give a brie[f] description.

The word *nebula* literally signifies a *clou[d]* or mist. This name is now used in astronom[y] to denote certain small spots, resemblin[g] whitish clouds, which are seen in the starr[y] heavens by the telescope, and which presen[t] different kinds of appearances, either that o[f] single stars enveloped in a nebulous veil, o[r] of groups of small stars, or only the appea[r]ance of a shining or glittering cloud: whic[h] last are the nebulæ properly so called. Th[e] following are some general observations o[n] the Nebulæ by Sir William Herschel. Th[e] success which accompanied the observatio[ns] of this eminent astronomer in reference to th[e] Milky Way, induced him to turn his te[le]scope to the nebulous parts of the heavens, [of] which an accurate list had been published in t[he] *Connoissance des Temps** for 1783 and 17[84]. Most of these yielded to a Newtonian reflec[tor] of 20 feet focal distance, and 12 inches ap[erture]

* *Connoissance des Temps*, or as it is so[me]times written, *Connaissance des Tems*, literal[ly] signifies *the knowledge of time*. It is the title [of] an Almanac, or astronomical ephemeris, pu[b]lished at Paris, on nearly the same plan as t[he] "Nautical Almanac," published at Londo[n]. The following is the title of one published in t[he] year 1825:—"Connaissance des Tems, ou d[es] Mouvemens Celestes, a l'Usage des Astronom[es] et des Navigateurs, pour l'an 1828. Publiee pa[r] le Bureau des Longitudes." It contains 2[7]6 pages

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that 'I found myself on nebulous ground.'" From these observations of Herschel, it appears that the nebulæ are not dispersed indiscriminately through the heavens, but are found in certain regions and directions rather than in others, and that, as formerly stated, they probably make the circuit of the heavens, intersecting at a certain angle the Milky Way.

More than eighty years ago, it was suggested by the celebrated mathematician and astronomer, M. Lambert, in his "Letters on Cosmogony," that all the stars in the universe are collected into systems; that all the systems are in motion; that the individual stars or suns of each system move round a common centre of gravity, which may possibly be a large opaque globe; and that all the systems of the universe, as one related system, revolve around some GRAND CENTRE, common to the whole. "All those systems of worlds," says this astronomer, "resemble, though on a small scale, the solar system, inasmuch as in each the stars of which it is composed revolve round a common centre, in the same manner as the planets and comets revolve round the sun. It is even probable that several individual systems concur in forming more general systems, and so on. Such, for example, as are comprehended in the Milky Way, will make competent parts of a more enlarged system; and this way will belong to other milky ways, with which it will constitute a whole. If these last are invisible to us, it is by reason of their immense distance. It would not be at all astonishing, if milky ways, situated still further from us in the depth of the heavens, should make no impression on the eye whatever." Again—"The sum of the milky ways taken together have their common centre of revolution; but how far soever we may thus extend the scale we must necessarily stop at last; and where? At the centre of centres, at the centre of creation, which I should be inclined to term the capital of the universe, inasmuch as thence originates motion of every kind, and there stands the great wheel in which all the rest have their indentation. From thence the laws are issued which govern and uphold the universe, or, rather, there they resolve themselves into one law of all others the most simple. But who would be competent to measure the space and time which all the globes, all the worlds, all the worlds of worlds, employ in revolving round that immense body—the Throne of Nature and the Footstool of the Divinity! What painter, what poet, what imagination is sufficiently exalted to describe the beauty, the magnificence, the grandeur of this source of all that is beautiful, great, magnificent, and from which order and harmony flow in eternal

streams through the whole bounds of the universe."

The discoveries made by Sir W. Herschel in reference to the nebulæ have in part realized some of the views suggested by Lambert in regard to the general arrangements of the systems of the universe. They afford convincing evidence that the stars are not dispersed as it were at random, in a kind of magnificent confusion, but are distributed systematically, in immense clusters, throughout the regions of boundless space.

There are various forms and classes of nebulæ which we shall notice in the sequel, but they may all be reduced to two great classes,—the *resolvable* and *irresolvable*; that is, those which may be resolved into clusters of stars by powerful telescopes, and those which no telescope hitherto constructed has yet been able to resolve into starry groups.

Prior to Sir W. Herschel's observations on the nebulæ, about a hundred of these objects had been descried in different parts of the heavens, of which an account had been given by Messier, as formerly stated. About 2000 more were afterwards discovered by the unwearied exertions of our British astronomer, a description of which was inserted at different periods in the Philosophical Transactions. The places of these were afterwards computed from his observations, and arranged into a catalogue, in the order of right ascension, by his sister, Miss Caroline Herschel, a lady singularly eminent for her astronomical knowledge, who assisted him in all his sidereal labours and discoveries, and was herself a discoverer of several interesting celestial phenomena, particularly comets. Her illustrious nephew, Sir John Herschel, read a paper before the Royal Society in November, 1833, in which he gives the places of 2500 nebulæ, or clusters of stars, of which 500 were detected by his own observations, the rest having been accurately determined by his father. Besides these, more than 500 nebulæ have been discovered in the southern hemisphere of the heavens, of which the Magellanic clouds are the most conspicuous and the most remarkable. They are three in number, two of them being near each other; the largest is at a considerable distance from the south pole, but the other two are only eleven degrees distant. To the naked eye, they appear like portions of the Milky Way.

These nebulæ have great variety of forms: some are comparatively bright, and others so obscure as to render it difficult to detect them in the field of the telescope, or to ascertain their shape. Some of them appear round, some oval, and others of a long elliptic shape; some exhibit an annular form, like luminous rings, and others like an ellipses with a dark space in the centre; but the greater number approximate to a roundish form. Of the 103 nebulæ inserted in Messier's list, eighteen were known at the time to consist of small stars; but Sir W. Herschel afterwards found twenty-six more of them to consist purely of clusters of stars, eighteen of small stars accompanied with nebulosity, and the remainder not resolvable into stars by the highest powers of his telescopes. It is evident that these objects, however apparently small and obscure, must be bodies of *immense magnitude*, when we take into consideration the vast distance at which they must be placed from our globe. The following are Sir W. Herschel's views on this point:

"My opinion of their size is grounded on the following observations:—There are many round nebulæ of about five or six minutes in diameter, the stars of which I can see very distinctly; and on comparing them with the visual ray calculated from some of my long gauges, I suppose, by the appearance of the small stars in those gauges, that the centres of these round nebulæ may be 600 times the distance of Sirius from us." He then goes on to show that the stars in such nebulæ are probably twice as much condensed as those of our system, otherwise the centre of it would not be less than 6000 times the distance of Sirius, and that it is possibly much underrated by supposing it only 600 times the distance of that star. "Some of these round nebulæ have others near them, perfectly similar in form, colour, and the distribution of stars, but of only half the diameter; and the stars in them seem to be doubly crowded, and only at about half the distance from each other. They are indeed so small as not to be visible without the utmost attention. I suppose these miniature nebulæ to be at double the distance from the first. An instance equally remarkable and instructive is a case where, in the neighbourhood of two such nebulæ as have been mentioned, I met with a third similar, resolvable, but much smaller and fainter nebula. The stars of it are no longer to be perceived; but a resemblance of colour with the former two, and its diminished size and light, may well permit us to place it at full twice the distance of the second, or about four or five times the distance of the first; and yet the nebulosity is not of the milky kind, nor is it so much as difficultly resolvable or colourless. Now in a few of the extended nebulæ, the light changes gradually, so as from the resolvable to approach to the milky kind; which appears to me an indication that the milky light of nebulæ is owing to their much greater distance. A nebula, therefore, whose light is perfectly milky cannot well be supposed to be at less than

six or eight thousand times the distance of Sirius; and though the numbers here assumed are not to be taken otherwise than as very coarse estimates, yet an extended nebula which in an oblique situation, where it is possibly foreshortened by one-half, two-thirds, or three-fourths of its length, subtends a degree or more in diameter, cannot be otherwise than of a *wonderful magnitude*, and may well OUTVIE OUR MILKY WAY IN GRANDEUR."

It appears to be a very natural conclusion, that the nebulæ which are perfectly similar in form, colour, and the distribution of stars, but only half the diameter, and the stars doubly crowded, are about *double the distance from the first*. And if the distance of the larger nebulæ, whose stars are distinctly seen, be at least 600 times the distance of Sirius, as there is every reason to believe, then the distance of those which are only half the diameter must be about 1200 times the distance of that star; that is at the very least, 24,000,000,000,000,000, or twenty-four thousand billions of miles. But the nebulæ whose light is "perfectly milky," or so far removed from us that the stars of which they are composed cannot be separately distinguished, may be justly considered as seven thousand times the distance of Sirius, or, in numbers, 168,000,000,000,000,000, or one hundred and sixty-eight thousand billions of miles!—a distance of which we can have no distinct conception. Light, notwithstanding its amazing velocity, would be nearly thirty thousand years ere it could fly from such nebulæ to the earth; and a cannon ball, with its utmost velocity, would require more than *thirty-eight thousand millions* of years before it could move over an equal space. Since the distance of these nebulæ is so immense, and since those which are among the largest and nearest are found by actual observation to be composed of countless numbers of stars, leaving us no room to doubt that the most distant are also immense systems of stars, how great must be *the magnitude*, and how inexpressible the grandeur, of the numerous luminaries of which they are composed!

I have stated above that more than three thousand nebulæ have already been discovered, and whose places in the heavens have been accurately determined, so that those who have access to powerful telescopes may have an opportunity of observing the greater part of them. From all the observations made by Sir W. Herschel, he is of opinion that our nebula, or the Milky Way, is *not* the most considerable in the universe; and he points out some very remarkable nebulæ which in his opinion cannot be less, but are probably *much larger*, than that of which our own sun and system form a part. Now, on these grounds let us consider what must be the extent and magnitude of only the *visible* universe. Supposing the number of stars composing the Milky Way to be ten millions, which is only half the number formerly assigned, (p. 73), and that each of the nebulæ at an average contains the same number; supposing, further, that only two thousand of the three thousand nebulæ are resolvable into clusters of stars, and that the other thousands are masses of a shining fluid not yet condensed into distinct luminous globes; the number of stars, or *suns*, comprehended in that portion of the firmament which is within the reach of our telescopes would be 20,000,000,000, or *twenty thousand millions*, which is twenty millions of times the number of all the stars visible to the naked eye.

Great as the number is, and magnificent and overpowering as the ideas are which it suggests of the extent of creation, yet these vast assemblages of systems may be no more than as a single nebula to the whole visible firmament, or even as a grain of sand to the whole earth, compared with what lies beyond the range of human vision, and is hid from mortal eye in the boundless and unexplored region of immensity! Beyond the boundaries of all that will ever be visible to the inhabitants of our globe, an infinite region exists, in which we have every reason to believe the Deity sits enthroned in all the grandeur of his overflowing goodness and omnipotence, presiding over innumerable systems, far surpassing in magnificence what "eye hath yet seen" or the most brilliant intellect can conceive. For we ought never for a moment to surmise that the operations of Almighty Power are exhausted at the point where the efforts of genius and art can no longer afford us assistance in tracing the footsteps of the Divinity through the mysterious regions of infinitude; nor should we ever suppose that man, placed on such a diminutive ball as the earth, and furnished with powers of so limited a nature as those with which he is now invested, will ever be able to grasp the dominions of Him who fills immensity with his presence, and "whose ways are past finding out."

## SECTION II.

### *On the various kinds of Nebulæ.*

I have already alluded to the different shapes or forms of nebulæ. These objects, on account of their appearing with different degrees of lustre, and assuming a great variety of shapes and modifications, have been arranged into different classes.

1. The first class is that of *clusters of stars*, in which the separate stars are clearly distin-

guished by good telescopes. This class is again divided into *globular* clusters, or those which appear of a roundish form, and somewhat compressed towards the centre; and *irregular* clusters, or those which are neither circular nor elliptical, but of a somewhat indefinite or angular form. These last are generally less rich in stars, and less condensed towards the centre, and are likewise less definite in their outline, so that their termination in many cases cannot be distinctly perceived. In some of them the stars are nearly all of the same size, in others extremely different; and "it is no uncommon thing," says Sir J. Herschel, "to find a very red star, much brighter than the rest, occupying a conspicuous situation in them." Sir W. Herschel regards these as globular clusters in a less advanced state of condensation, conceiving all such groups as approaching, by their mutual attraction, to the globular figure, and assembling themselves together from all the surrounding region, under laws of which we have no other proof than the observance of a gradation by which their characters shade into one another, so that it is impossible to say where one species ends and the other begins." Fig. 41, formerly referred to, represents one of the globular clusters in the constellation Hercules. Fig. 42 is a view of a curious but somewhat irregular group, seen in the southern hemisphere, as sketched by Mr. Dunlop, at Paramatta, New South Wales. It is the 30 Doradus, or Xipheas, and is rather a singular object, but evidently a large cluster of stars, presenting two or three very condensed strata, as if they were crowded to excess by an immense confluence of stars.

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2. Another class is that termed *resolvable nebulæ*, or those which lead us to suppose that they consist of stars which would be separately distinguishable by an increase of light and magifying power in the telescope. These may be considered as clusters too remote to be distinctly seen, the stars composing which are either too faint in their light or too small in size to make a definite impression upon the organs of vision. They are almost universally round or oval, which is supposed to be owing to their loose appendages and irregularities of form being extinguished by their distance, the general figure of the central or more condensed parts being only discernible. "It is under the appearance of objects of this

character," says Sir J. Herschel, "that all the greater globular clusters exhibit themselves in telescopes of insufficient optical power to show them well; and the conclusion is obvious that those which the most powerful can barely render *resolvable*, would be completely *resolved* by a further increase of instrumental force.

3. Besides the above, there is an immense variety of nebulæ, *properly so called*, which no telescopes have hitherto been able to resolve into stars, and which is supposed to be a species of matter diffused throughout infinite space, in various portions and degrees of condensation, and which may, in the course of ages, be condensed into stars or starry systems. The following is a description of some of the more remarkable varieties of this class of nebulæ.

Fig. 48 represents a nebula of an elliptical or spindle-like form. It is visible to the naked eye in a clear night, when the moon is absent, and has sometimes been mistaken for a small comet. It appears like a dull, cloudy, undefined

## PLATE V.

### MINIATURE MAP OF THE HEAVENS, ON MERCATOR'S PROJECTION, SHOWING THE COURSE OF THE MILKY WAY.

spot upon the concave of the firmament, and has sometimes been compared to the light of a small candle shining through horn. Its central parts appear brightest, but its light gradually fades towards each extremity. A few small stars appear adjacent to it, and even within its boundaries, but it appears pretty evident that they have no *immediate* connexion with the nebula. Its form, as here delineated, may be seen with a telescope of moderate power, but no telescope hitherto constructed, even with the highest powers that could be applied, has yet been sufficient to resolve it into stars. In size, it is nearly half a degree long, and 12 or 15 minutes broad. Though the figure of this object appears oval or elliptical, it is not unlikely that it is in reality nearly of a globular figure, and that its oval appearance is owing to its position with regard to our eye. This nebula is situated in the girdle of Andromeda, within a degree or two of the star $\nu$ of that constellation. It is about 15° nearly west from *Almaach*, and 8° north by west of *Merach*, with which stars it forms nearly a right-angled triangle. It may be seen in a north-westerly direction in the evenings of the months of January, February, and March, at a considerable elevation. It comes to the meridian about the middle of November, at nine o'clock in the

evening. Its right ascension is 0h 33′; and north declination, 40° 20′. This nebula may be considered as a representative, on a large scale, of a numerous class of nebulæ, which increases more or less in density towards the central point. The representation of it in the plate is somewhat longer and narrower than it appears through a telescope magnifying 140 times.

Fig. 44 represents a kind of elliptical nebula, with a vacancy of a lenticular form in the centre. It is pretty evident that such nebulæ are in reality large rings, which appear of an oval or lenticular form in consequence of their lying obliquely to our line of vision. This is undoubtedly a large starry system, comprising perhaps millions of stars, at such a distance that their combined light appears only like a faint nebula. It probably is not much unlike the form of our Milky Way in which the sun is situated. Its right ascension is 2h 12′, and north decl. 41° 35′. It lies near γ Andromeda, or *Almaach*, about 4° to the eastward of that star, nearly in a line between it and *Algol*, in the head of Medusa, and about 19° east from the nebula represented in Fig. 43.

Fig. 45 is a representation of an *annular* nebula, which may be seen with a telescope of moderate power. It does not occupy so much space in the heavens as the preceding nebulæ, but it is well defined, and has the appearance of a flat, solid ring. It is not perfectly circular, but somewhat elliptical, the conjugate axis of the ellipse being to the transverse nearly to the proportion of 4 to 5. The opening occupies about half its diameter, and is not entirely dark, but filled up with a very faint hazy light, uniformly spread over it. Its light is not of a pure milky white, but is somewhat mottled in its appearance near the exterior edge. This curious phenomenon, like the preceding, is doubtless an immense stellar system, situated at an immeasurable distance in the profundity of space. It is situated in the constellation of Lyra, exactly half-way between the stars β and γ, so that its position may be found by common observers without any difficulty. Its right ascension is 18h 47′; and north declination, 32° 49′. The following cut (fig. 46) represents some of the principal stars in the constellation of the Lyre. The largest star near the upper part is *Vega*, a bright star of the first magnitude; the next larger star, south by east of which is β; and the other star of the same magnitude to the south-east is γ; between which is the annular nebula, about 7½° from Vega.

Fig. 46 represents an object somewhat similar to the above. It is situated between the constellations Anser and Cygnus, about 9½° south from the star γ Cygni, and 17° east from the phenomenon described above.* Its right ascension is 20h 9′; and north declination, 30° 9′.

Fig. 46.*

*North.*


It comes to the meridian about the 10th of September, at nine o'clock in the evening.

The opposite page contains representations of several other kinds of nebulæ, some of which are extremely curious and singular. Fig. 47 is a very singular and wonderful object. It has the shape of a dumb-bell or hour-glass of bright matter, surrounded by a thin hazy atmosphere; the two connected hemispheres, and the space which connects them, are beautiful and pretty bright. The oval is completed by a space on each side, which is much more dim and hazy than the two hemispheres. The whole has an oval form, like that of an oblate spheroid. The southern hemisphere is somewhat denser than the northern, and there are one or two stars in it. It appears evidently to be a dense collection of stars, at an immeasurable distance from the region in which we reside, and leads us to form an idea of the endless diversities of shape and form among those countless assemblages of stars with which the universe is replenished. This nebula is situated in right ascension, 19h 52′; north declination, 22°

* It may not be improper here to remark, once for all, that the bearings or directions of the stars from one another, given here and in other parts of this volume, are strictly applicable only when the principal star, from which the bearings are stated, *is on or near the meridian*. When in other positions, they will appear to a common observer to have different bearings; for example, the star *Vega* or Lyra, in the above figure, when about 50° or 60° above the western horizon, will appear at an equal altitude as the star β, south-west by south of it; and when about 30° or 40° above the eastern horizon, the two stars will appear, the one directly above or below the other. This difference in the apparent directions of the stars from each other is most observable in those which are near the pole; for example, the stars of the Great Bear appear in one part of their revolution west from the pole, and in another part of their course east of it. These and other circumstances require to be attended to, in order to find particular stars by their bearings from one or more principal stars.

16′; in the breast of Anser et Vulpecula, about midway between Albireo in the Swan, and the principal stars of the Dolphin, about three or four degrees north of Sagitta, a star of the fourth magnitude.

Fig. 48 is likewise a very remarkable object. It consists of a bright round nucleus, or central part, surrounded at a great distance by a nebulous ring. This ring appears split through nearly the greater part of its circumference, the two portions of which being separated at about an angle of 45°. This nebula lies near the remotest boundaries to which our telescopes can carry us. It has never been resolved into stars by the highest powers that have yet been applied; but there is little doubt that it is a grand scheme of sidereal systems, perhaps exceeding our Milky Way in number and magnificence. It is indeed supposed to bear a more striking resemblance to the system of stars in which the sun is placed than any other object which has yet been discovered in the heavens, as may be perceived by turning to figure 39, (p. 76,) which represents Sir W. Herschel's scheme of the Milky Way; and hence Sir John Herschel describes it as "a brother system, bearing a real physical resemblance and strong analogy of structure to our own." This object, dim and distant as it may appear through our telescopes, and utterly invisible as it is to the unassisted eye, may be considered as a kind of universe in itself, ten thousand times more grand and extensive than the whole creation was supposed to be in the infancy of astronomy. Like the preceding nebula, it shows us what singular varieties of structure are to be found in the systems which compose the universe, and at the same time it exhibits a certain resemblance to another system of which we form a part; and perhaps something similar, though not precisely of the same form and arrangement, may be found in other parts of the sidereal heavens. This phenomenon is situated near the back of Asterion, about five degrees south by west of *Benetnasch*, the last star in the tail of the Great Bear; between which star and the nebula there is a small star of the fifth magnitude, nearer to the nebula than to Benetnasch. Its right ascension is $13^h\ 22'$; and north declination, 46° 14′.

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Figures 49, 50, 52, 53, 54, 55, 56, 57, and 58, represent some specimens of *nebulous stars*, or of nebulæ connected with very small stars,

Figure 49 shows a nebulosity, or something like a nebulous stream, extending from one small star to another, as if there was a communication between them. The next three figures are representations of similar phenomena. In figure 53

30 the nebulous substance appears much broader than in the others, though this may possibly be owing to the nebula in its greatest extent being presented to our line of vision.

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Figures 54, 55, 56, are very small stars, with faint and small

51 nebulæ attached to them in the shape of a puff. Fig. 57 is a small star, with a small, faint, fanshaped nebulosity joined to it. Fig. 58 represents two considerable stars involved in a very faint nebulosity of three or four minutes in extent.

52 What this nebulous substance in reality is, or what connexion it may have with the stars which appear in its vicinity, it is difficult to conjecture. It is a species of nebulæ which does not appear to be resolvable into stars, and therefore may be regarded as a distinct luminous substance diffused throughout different regions of the universe, subserving some important designs in the physical economy of creation of which we are ignorant. Speci-

65 64 63

mens of some of these phenomena will be found in the following situations:—1. Right ascension, $20^h 56'$; north declination, $11° 24'$; a little to the east of the cluster of stars called the Dolphin. 2. Right ascension, $8^h 46'$; north declination, $54° 25'$; about seven degrees north-west of the star *Theta* of the Great Bear. 3. Right ascension, $12^h 51'$; north declination, $35° 47'$; about four degrees south of the star *Cor Caroli*, the principal star in the Grayhounds. 4. Right ascension, $6^h 30'$; north declination, $8° 53'$; which is in the head of Monoceros, or the Unicorn, about eleven degrees east of Betelguese, in the right shoulder of Orion, and about seven degrees due south of Gemini, which is in the left foot of one of the Twins.

Figures 59 to 65 represent a few specimens of objects which come under the denomination of *extensive diffusive nebulosities*. These phenomena were very little noticed till lately, and can only be perceived by telescopes of large aperture, which collect a great quantity of light. In adverting to one of these objects, Sir W. Herschel describes it as follows:—"Extreme faint branching nebulosity;

its whitishness is entirely of the milky kind, and it is brighter in three or four places than the rest; the stars of the Milky Way are scattered over it in the same manner as over the rest of the heavens. Its extent in the parallel is nearly one degree and a half, and in the meridianal direction about fifty-two minutes." It appears that this diffused nebulosity is very extensive; for of fifty-two nebulæ of this description which had never been before observed, Herschel found them to occupy no less than 152 square degrees. A specimen of an extensive diffusive nebula of this description is represented in fig. 59

Sir W. Herschel has presented us with fourteen specimens related to this class, of what he terms *nebulosities joined to nebulæ*, one of which is represented in fig. 60, where a bright nebulous speck is connected with a faint nebulosity, which seems to proceed from it as from a central point, increasing in breadth in proportion to the distance, till it terminates in a kind of irregular margin. Fig. 61 represents what is called a *milky nebula with condensation*. It appears to be a roundish nebula, condensed towards the central parts. It is natural to suppose, when we see a gradual increase of light, that there is a condensation of the substance which produces it in the space which appears brightest, or at least that the luminous substance is *deeper* in the brighter space. Some of the nebulosities of this class are not always extensively diffused, but are sometimes met with in detached collections, near to each other, but completly separate, as represented at *a b*, *c*, fig. 62.

A diffused nebulosity of this kind may be seen about six or seven degrees due east from the star *Zeta* Cygni, near the back or tail of Anser. Its right ascension is 20h 38′, and north declination, 30° 6′. Another, whose right ascension is 20h 49′, and north declination 31° 3′, is found about three or four degrees north-west of *Zeta* Cygni, and within two or three degrees of the preceding.

Figures 63, 64, and 65, are representations of nebulæ which are brighter in more than one place, which appearance is supposed to be owing to so many predominant seats of attraction, owing to a superior preponderance of the nebulous matter in those places causing a division of it from which will arise three or four distinct nebulæ.

Figures 66 to 71 are representations of nebulæ of various descriptions. The three upper figures, numbered 66, are nebulæ that are *suddenly much brighter in the middle*.

A nucleus to which these nebulæ seem to approach is considered as indicating consolidation; and that, should we have reason to conclude that a solid body can be formed of condensed nebulous matter, the nature of which has been chiefly deduced from its shining quality, we may possibly be able to view it with respect to some other of its properities. The three figures, No. 67, represent *extended nebulæ and round nebulæ, that show the progress of condensation.* These nebulæ appear further condensed than the preceding, and appear surrounded with the rarest nebulous matter, which, not having as yet been consolidated with the rest, remains expanded about the nucleus in the shape of a very extended atmosphere. The three figures in the third row from the top of the plate, marked No. 68, and the first figure to the left hand of No. 69, represent nebulæ which are almost of an uniform light, and nebulæ that draw progressively towards a period of final condensation. "In the course of the gradual condensation of the nebulous matter," says Sir W. Herschel, "it may be expected that a time must come when it can no longer be compressed, and the only cause which we may suppose to put an end to the compression is, when the consolidated mass assumes hardness. From the size of the nebulæ, as we see them at present, we cannot form an idea of the original bulk of the nebulous matter they contain; but let us admit, for the sake of computation, that the nebulosity of a certain nebula, when it was in a state of diffusion, took up a space of ten minutes in every cubical direction of its expansion, then, as we now see it collected into a globular compass of less than one minute, it must of course be more than 1900 times denser than it was in its original state. This proportion of density is more than double that of water to air."

The small nebulæ represented in No. 70 are *stellar nebulæ*, which approach to the appearance of stars, and one or two of doubtful character. The four figures marked No. 71, represent separate views of the gradual condensation of the nebulous substance. In these we may evidently perceive a striking gradation in the light and brilliancy of the central parts. The figure on the left hand side represents an object nearly in its original state of nebulosity; the next towards the right appears considerably condensed towards the central parts; the third figure represents a condensation still greater; and the one on the right hand exhibits a condensation nearly complete, or a huge luminous body surrounded with a lucid atmosphere. Each of these is the representative of an extensive class of objects of this description.

## Section III.

### *On Planetary Nebulæ.*

This designation is given to a class of nebulæ which bear a very near resemblance to planetary disks when seen through telescopes. But, notwithstanding their planetary aspect, some small remaining haziness, by which they are more or less surrounded, evinces their nebulous origin. They are somewhat extraordinary objects, with round or slightly oval disks, in some instances quite sharply terminated, in others, a little hazy at the borders, and of a light exactly equable, or only a very little mottled, which in some of them approaches in vividness to the light of actual planets. The following are some of Sir W. Herschel's remarks on these bodies:—If we should suppose them to be single stars with large diameters, we shall find it difficult to account for their not being brighter, unless we should admit that the intrinsic light of some stars may be very much inferior to that of the generality, which, however, can hardly be imagined to extend to such a degree. We might suppose them to be comets about their aphelion, if the brightness as well as magnitude of their diameters did not oppose this idea; so that, after all, we can hardly find any hypothesis so probable as that of their being nebulæ; but then they must consist of stars that are compressed and accumulated in the highest degree. At a subsequent period, Sir William remarks, "When we reflect on the circumstances connected with these bodies, we may conceive that, perhaps, in progress of time these nebulæ which are already in a state of compression may be still further compressed so as actually to become stars. It may be supposed that solid bodies such as we suppose the stars to be, from the analogy of their light, with that of our sun when seen at the distance of the stars, can hardly be formed of a condensation of nebulous matter; but if the immensity of it required to fill a cubical space which will measure ten minutes, when seen at the distance of a star of the eighth or ninth magnitude, is well considered, and properly compared with the very small angle our sun would subtend at the same distance, no degree of rarity of the nebulous matter to which we have recourse can be any objection to the solidity required for the construction of a body of equal magnitude with our sun."

The nature of these nebulæ is involved in considerable darkness and mystery. As in the case of some of the other species of these phenomena, so in this, the mind feels unable to form any definite or satisfactory conceptions on the subject. The following remarks of Sir J. Herschel comprise most of what can

be stated, in the mean time, on this subject:—"Whatever be their nature, they must be of enormous magnitude. One of them is to be found in the parallel of ν Aquarii, and about five minutes preceding that star. Its apparent diameter is about twenty seconds. Another, in the constellation Andromeda, presents a visible disk of twelve seconds perfectly defined and round. Granting these objects to be equally distant from us with the stars, their real dimensions must be such as would fill, on the lowest computation, *the whole orbit of Uranus*. It is no less evident that, if they be solid bodies of a solar nature, the intrinsic splendour of their surfaces must be almost infinitely inferior to that of the sun's. A circular portion of the sun's disk, subtending an angle of twenty seconds, would give a light equal to 100 *full moons*, while the objects in question are hardly, if at all, discernible with the naked eye. The uniformity of their disks, and their want of apparent central condensation, would certainly augur their light to be merely superficial, and in the nature of a hollow superficial shell; but whether filled with solid or gaseous matter, or altogether empty, it would be a waste of time to conjecture."

In this description there is nothing which strikes the mind with such astonishment as the *enormous magnitude* of these planetary nebulæ. A globular body which would fill the orbit of Uranus would contain 24,429,-081,600,000,000,000,000,000,000, or more than twenty-four thousand *quartillions* of solid miles. The solid contents of the sun is about 357,000,000,000,000,000, or three hundred and fifty-seven thousand *billions* of cubical miles. If the former number be divided by the latter, the quotient will be 68,428,800,000, showing that the nebula in question would contain within its circumference sixty-eight thousand, four hundred and twenty-eight millions, and eight hundred thousand globes as large as the SUN. A body of such bulk is more than thirty-four billions, two hundred thousand millions of times larger than all the primary planets and their satellites which belong to our system. What is the special destination of such huge masses of matter, or what important designs they subserve in the physical and moral arrangements of the Governor of the universe, it is beyond our power, in the mean time, to form even a probable conjecture. Future generations may perhaps be enabled to throw some light on this subject, though it is probable that the nature, properties, and ultimate designs of many such objects will only be fully disclosed throughout the revolutions of that interminable duration which succeeds the short span of human existence; but of this we may rest assured, that they are *not useless* masses of materials in the universe, but are subservient to purposes worthy of Him whose wisdom is infinite, and whose understanding is unsearchable.

The four figures towards the right hand of the plate, marked No. 69, represent some specimens of planetary nebulæ. One of those bodies may be seen near the star ν Aquarii, as above stated. Its right ascension is nearly $20^h\ 52'$, and its south declination about $12^\circ\ 26'$. It lies north by west of the star *Deneb Algedi*, at the distance of about ten degrees. Other nebulæ of this description may be found near the following stars:—3 *p* Sagittæ, 14 Andromeda, 63 *b* Crateris, 61 *g* Sagittæ, 10 Camelopardus, 36 Ursæ Majoris, 6 Navis, and 6 Draconis. About three minutes west from the star 16 *c* Cygni the following phenomenon is found:—A bright point a little extended, like two points close to each other. It is as bright as a star of the eighth or ninth magnitude, surrounded by a very bright milky nebulosity, suddenly terminated, having the appearance of a planetary nebula with a lucid centre. The border is not well defined; it is perfectly round, and about one minute and thirty seconds in diameter. This is a beautiful phenomenon, and of a middle species between the planetery nebulæ and nebulous stars.

Sir John Herschel, during his late residence at the Cape of Good Hope, is said to have discovered several new and singular objects in the southern hemisphere, some of them bearing a certain relation to the objects now described; among others, he is said to have detected a beautiful planetary nebula, which presents a perfectly sharp, well-defined disk of uniform brightness, exhibiting the exact appearancce of a small planet with a satellite near its margin. The regular compactness and globular form of such objects seem to indicate that they are bodies *sui generis*, neither collections of distinct stars nor exactly of the same nature with the other masses of nebulous matter dispersed through the heavens. They seem to present a view of an immense system already completed, but of what nature it would be vain to conjecture. Another phenomenon of this kind is stated as being of an extraordinary nature, on account of the *blue* colour which its light exhibits. He has likewise discovered a close double star involved in the centre of a nebulous atmosphere, which is considered as a new and singular object.

## SECTION IV.

### *On the Nebula in Orion.*

One of the largest and most remarkable nebula in the heavens is that which is found in the constellation of Orion. When a com-

mon observer looks at that constellation, the first object that arrests his attention is the three brilliant stars equi-distant from each other in a straight line, which is called the *belt* of Orion. Immediately below these, hanging down as it were from the middle of the belt, three small stars at nearly equal distances are perceived, which are termed *the sword*. On directing the naked eye to the middle star of the three, the observer perceives something that has the appearance of a small star, but not well defined; this is the great nebula of Orion: of which, however, he can form no definite conception till his eye be assisted by optical instruments. With a common one-foot pocket achromatic telescope the nebulosity may be plainly perceived; but the higher the magnifying power, and the larger the aperture of the object glass, the more brilliant and distinct does this phenomenon appear, along with a number of small stars connected with it, which are quite invisible to the unassisted eye.

The first who discovered this phenomenon was the celebrated Huygens, who gave the following description of it in his *Systema Saturnium*:—"Astonomers place three stars close to each other in the sword of Orion, and when I viewed the middlemost with a telescope in the year 1656, there appeared, in the place of that one, twelve other stars; among these, three that almost touch each other, and four more besides appeared twinkling as through a cloud, so that the space about them seemed much brighter than the rest of the heavens, which appearing wholly blackish, by reason of the fair weather, was seen as through a certain opening, through which one had a free view into another region which was more enlightened. I have frequently observed the same appearance in the same place, without any alteration; so that it is likely that this wonder, whatever it may be in itself, has been there from all times; but I never took notice of any thing like it among the rest of the fixed stars."

Fig. 72 exhibits a view of this phenomenon as seen by Dr. Long in 1741 with a seventeen-feet refracting telescope, which appears exactly the same shape as originally delineated by Huygens; but the apparent magnitudes of the stars connected with it are more accurately shown than in the engraved delineation of Huygens. Dr. Long says that the luminous space has sometimes appeared to him nearly of the same shape as the figure which is formed by the seven stars within it. Fig. 73 represents the same nebula, as seen by Sir W. Herschel in the year 1774 and in 1811. Its shape appears considerably different from the delineations of Huygens and Dr. Long; but the stars within and around it, which are common to both delineations, appear nearly in the same relative position. Sir John Herschel has given a representation of this nebula, as viewed through the twenty-feet reflector at Slough, which appears considerably different from the figures to

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which I have referred. I have frequently viewed this phenomenon with telescopes of different sizes, particularly with a six feet and a half achromatic, having an aperture of four inches diameter, and which showed sidereal objects with great brilliancy and distinctness; but the shape of the object appeared more nearly resembling Dr. Long's representation (fig. 72) than any other delineation I have seen. A fourth star was distinctly seen in addition to the three represented by Dr. Long near the head of the opening, but smaller than the other three, and forming with them a small irregular square. The three other stars, instead of being *within* the one side of the nebula, as represented in both the figures, appeared quite beyond it, but nearly in a line with its margin. Whether this was owing to the inaccuracy of the delineation or to the actual change of the nebula I do not pretend to determine. The left-hand branch of the nebula likewise appeared considerably longer than here represented; but I cannot pretend to say what the appearance may be as seen through a twenty-feet reflecting telescope.

In forming a proper conception of this object, it is of some importance to ascertain the exact appearance it has presented at different periods, and whether there be reason to conclude that it has been subject to changes. The following is Sir J. Herschel's description of this phenomenon:

"I know not how to describe it better than by comparing it with a curdling liquid, or a surface strewed over with flocks of wool, or to the breaking up of a mackerel sky, when the clouds of which its consists begin to assume a cirrous appearance. It is not very unlike the mottling of the sun's disk, only, if I may so express myself, the grain is much coarser and the intervals darker, and the flocculi, instead of being generally round, are drawn into little wisps. They present, however, an appearance of being composed of stars, and their aspect is altogether different from that of resolvable nebulæ. In the latter we fancy by glimpses that we see stars, or that could we strain our sight a little more we would see them; but the former suggests no idea of stars, but rather of something quite distinct from them."

The following are some of Sir W. Herschel's remarks on this nebula, and on the stars with which it is connected:

"In the year 1774, the 4th of March, I observed the nebulous star which is the 43d, of the *Connoissance des Temps*, and is not many minutes north of the great nebulæ; but at the same time I also took notice of two similar, but much smaller, nebulous stars, one on each side of the large one and at nearly equal distances from it. (See fig. 73, &c.) In 1783, I examined the nebulous star, and found it to be faintly surrounded with a circular glory of whitish nebulosity, faintly joining it to the great nebulæ. About the latter end of that year, I remarked that it was not equally surrounded, but most nebulous towards the south. In 1784, I began to entertain an opinion that the star was not connected with the nebulosity of the great nebulæ of Orion, but was one of those which are scattered over that part of the heavens. In 1801, 1806, and 1810, this opinion was fully confirmed by the gradual change which happened in that great nebulæ to which the nebulosity surrounding the star belongs; for the intensity of light about the nebulous star had by this time been considerably reduced by the attenuation of dissipation of the nebulous matter, and it seemed now to be pretty evident that the star is far behind the nebulous matter, and that consequently its light in passing through it is scattered and deflected so as to produce the appearance of a nebulous star." .... "When I viewed this interesting object in December, 1810, I directed my attention particularly to the two nebulous stars by the sides of the large one, and found they were perfectly free from every nebulous appearance, which confirmed not only my former surmise of the great attenuation of the nebulosity, but also proved that their former nebulous appearance had been entirely the effect of the passage of their feeble light through the nebulous matter spread out before them. The 19th of January, 1811, I had another critical examination of the same object, in a very clear view, through the forty-feet telescope; but notwithstanding the superior light of this instrument, I could not perceive any remains of nebulosity about the two small stars, which were perfectly clear, and in the same situation where about thirty-seven years before I had seen them involved in nebulosity. If, then, the light of these three stars is thus proved to have undergone a visible modification in its passage through the nebulous matter, it follows that its situation among the stars is less distant from us than the largest of the three, which I suppose to be of the eighth or ninth magnitude. The furthest distance, therefore, at which we can place the faintest part of the great nebula in Orion, to which the nebulosity surrounding the star belongs, cannot well exceed the region of the stars of the seventh or eighth magnitude."

From these observation it would appear that the nebulosities connected with the great nebula are subject to certain changes, and that its distance from our system is less than that of stars of the eighth magnitude, since a portion of the nebulous matter interposes between our sight and stars of this description.

But this distance must be very great. If stars of the eighth magnitude are to be considered at an average as eight times further distant than those of the first, then this nebula, cannot be supposed to be less than 320,000,000,000,000, or three hundred and twenty billions of miles from the earth. If its diameter at this distance subtend an angle of ten minutes, which it nearly does, its *magnitude* must be utterly inconceivable. It has been calculated that it must exceed 2,000,000,000,000,000,000, or two trillions of times the dimensions of the *sun*, vast and incomprehensible as these dimensions are.

This nebula has never yet been resolved into stars by the highest powers of the telescope that have yet been applied; nor is there any reason to believe that it consists of a system of stars, as is the case with many other nebulæ which appear much smaller, and are evidently more distant. It is therefore, in all probability, a mass of self-luminous matter not yet formed into any system or systems, but of what nature it would be vain to conjecture. Whether it is more condensed than when it was first observed nearly two hundred years ago, as some have conjectured, or whether any portions of it have shifted their position, as seems to have been the opinion of Sir W. Herschel from the observations above stated, appears on the whole somewhat uncertain. On this point Sir J. Herschel makes the following remark:—"Several astronomers, on comparing this nebula with the figures of it handed down to us by its discoverer, Huygens, have concluded that its form has undergone a perceptible change; but when it is considered how difficult it is to represent such an object, duly, and how entirely its appearance will differ even in the same telescope, according to the clearness of the air, or other temporary causes, we shall readily admit that we have no evidence of change that can be relied on."

The phenomenon we have now been contemplating is calculated to suggest a train of reflections and inquires—What is the grand design in the system of nature of such an immense mass of luminosity—a mass of luminous matter to which the whole solar system is but only as a point—a mass at least twenty-nine millions of times larger than a globe which *would fill the orbit of Uranus?** Is it in a state of perfection completely answering the ultimate end of its creation, and will it remain for ever in that state? Or, is it only a chaotic mass of materials progressing towards some glorious consummation in the future ages of eternity, when worlds and systems will be evolved from the changes and revolutions now going forward within its boundaries? Or, may we suppose that a luminosity of so vast extent serves the purpose of a thousand suns to ten thousands of opaque globes which revolve within its wide circumference? Considering the diversified methods of Divine operation, and the vast variety of modes by which worlds are arranged and enlightened, it is not imposible, nor even improbable, that numerous worlds may be in this way illuminated with a perpetual and uninterrupted day. As there appear to be worlds connected with one sun, with two, with three, and even more suns, so there may be thousands of worlds cheered and illuminated without such a sun as ours, and with an effulgence of light which is common to them all. But on these points we shall never be able to arrive at certainty so long as we sojourn in this sublunary sphere. Suffice it to say, that such an enormous mass of luminious matter was not created in vain, but serves a purpose in the divine arrangements corresponding to its magnitude and the nature of its luminosity, and to the wisdom and intelligence of Him whose power brought it into existence. It doubtless subserves some important purposes, even at the present moment, to worlds and beings within the range of its influence. Were we placed as near it as one-half the distance of the nearest star, great as that distance is, from such a point it would exhibit an effulgence approximating to that of the sun; and to beings at much nearer distances it would fill a large portion of the sky, and appear with a splendour inexpressible. But the ultimate design of such an object, in all its bearings and relations, may perhaps remain to be evolved during the future ages of an interminable existence; and, like many other objects in the distant spaces of creation, it excites in the mind a longing desire to behold the splendid and mysterious scenes of the universe a little more unfolded.

## Section V.

### *On the Nebular Hypothesis.*

I have already stated that the nebulæ may be arranged into two classes, the *resolvable* and *irresolvable.* When Sir W. Herschel commenced his observations on the nebulous part of the heavens, and for several years afterwards, he was disposed to consider the nebulæ in general to be no other than clusters of stars disguised by their very great distance; but a long experience and better acquaintance with the nature of nebulæ convinced him that such a principle ought not to be universally admitted, although a cluster of stars may undoubtedly assume a nebulous appearance when it is too remote for us to

* See page 93.

discern the stars of which it is composed. When he perceived that additional light had no effect in resolving certain nebulæ into stars, he was forced to the conclusion, that though milky nebulæ may contain stars, yet there are also nebulosities which are not composed of them, nor immediately connected with them.

Hence astronomers have been constrained to admit the existence of a certain species of fine luminous matter, distinct from stars, or planets, or any other materials existing around us, which is diffused in immense masses throughout the spaces of the universe. The large nebula in Orion, described above, is considered as one of the most striking evidences that such a substance is distributed throughout the sidereal regions; for the whole light and power of Herschel's forty-feet telescope, though four feet in aperture, was insufficient to resolve it into stars, although from certain circumstances it appears to be one of the nearest, as it is one of the brightest, of those nebulous masses. It has therefore become a subject of interesting inquiry, "What are those huge masses of unformed matter we call the nebulæ? and what purposes do they serve in the economy of creation?"

It is an opinion now very generally entertained, that the self-luminous matter to which we refer is the chaotic materials out of which new suns or worlds may be formed, and that it is gradually concentrating itself by the effect of its own gravity, and of the circular motions of which it may be susceptible, into denser masses, so as ultimately to effect the arrangement and establishment of sidereal systems. It is argued that this opinion is highly probable, from the consideration that we find the nebulæ in almost *every stage of condensation*. Such nebulæ as are represented in Figures 59 and 62 are viewed as consisting of nebulous matter in its rudest and most chaotic state; and Figures 63, 64, 65, and also Figures 66, 67, 68, as similar matter in a state of progress towards condensation. The four figures marked 71 are considered as specimens of this gradual condensation, in which the progress may be traced from the left-hand figure to the right. It has ever been maintained by some late writers on this subject that this, in all probability, is the mode in which the different systems of the universe were gradually brought into the state in which we now behold them, and that the sun and planets of the system to which we belong derived their origin from a similar cause; and it has likewise been attempted to connect the geological changes in the structure of our globe with the operation of a principle or law by which such a thin filmy substance as a nebula was condensed into such a heterogeneous mass of solidity as we find in the constitution of the terraqueous globe; and it has been insinuated that the zodiacal light is a portion of the original nebula of which the sun and planets were formed, and a presumptive evidence that the nebular hypothesis is true. According to these theorists, the sun is still to be considered as a nebulous star in a high state of condensation, and may exhibit such an appearance when viewed from a neighbouring system.

Such conclusions, to say the least, are obviously premature. We know too little, in the mean time, of the nature of that nebulous matter which is dispersed through the heavens, or of the motions with which its particles may be endued, to be able to determine its susceptibility of being condensed and arranged into suns and planets. We have never yet seen the same nebula progressing from one stage of condensation to another, from a chaotic to a state of organization; nor is it likely we ever shall, even supposing the hypothesis to be well founded, as an indefinite number of years, or even of ages, must be requisite before such a revolution can be accomplished. Yet the observations of future astronomers on this department of the sidereal heavens may tend to throw some additional light on this mysterious subject.

It forms no conclusive argument, however, against this hypothesis that it is difficult to conceive how a fluid of a nature so apparently rare can ever be condensed to the hardness of a planet or a sun; for if we suppose a nebulosity in its most diffused state to be twenty minutes in diameter, and to be compressed by central attraction and rotary motion till it become only one minute in diameter, the ratio of its density in the latter state compared with that of the former would be as eight thousand to one, since spheres are to each other as the cubes of their diameters. Suppose its density in the first state were equal to that of atmospheric air; its density, when compressed in the proportion supposed, would be nine times heavier than water, which is nearly equal to the weight of silver, and twice the average density of our globe; but if such a process be going on in any of these bodies, numerous ages must elapse before such a consolidation can be effected, for no sensible change appears to have taken place during the period in which such bodies have come under our observation.

Nor do we conceive that this hypothesis is inconsistent with what we know of the attributes and operations of the Almighty; for all the movements and changes going on in our terrestrial system and throughout the universe are the effects of certain laws impressed upon matter by the hand of the Creator, by the

uniform operation of which his wise and beneficient designs are accomplished. If, then, it forms a part of his designs that new suns and systems shall be formed to diversify the spaces of immensity, and if he has created huge masses of subtile luminous matter, and endued them with certain gravitating powers and rotary motions for this purpose, his almighty agency and infinite wisdom may be as clearly and magnificently displayed in this case as if a system of worlds, completely organized, were to start into existence in a moment. Perhaps the gradual evolution of his designs in such a case might afford matter of admiration and enjoyment to certain orders of superior beings who are privileged to take a near view of such stupendous operations. But supposing such physical processes going forward, we must necessarily admit that *a direct interference of the Deity is necessary before such worlds*, after being organized, *can be replenished with inhabitants;* for matter and motion, by whatever laws they may be directed, cannot be supposed to produce the organization of a plant or an animal, much less of a rational being, whose intellectual principle and faculties must be communicated by the immediate "inspiration of the Almighty." To suppose otherwise would be virtually to adopt a species of atheism.

All that we require on this point is some more direct and decisive proofs of the validity of the hypothesis we are now considering; and till such proofs be elicited we are not warranted to enter into particular speculations, and to speak with so much confidence on the subject as certain theorists have lately done. Sir John Herschel, who has paid more attention to this subject, and made more accurate observations on this nebulæ, than almost any other individual, is far from being confident, and speaks with becoming hesitation and modesty in relation to this hypothesis. "If it be true," says he, "that a phosphorescent or self-luminous matter exists, disseminated through extensive regions of space in the manner of a cloud or fog,—now assuming capricious shapes like actual clouds drifted by the wind, and now contracting itself like a cometic atmosphere around particular stars—what, we naturally ask, is the nature and destination of this nebulous matter? Is it absorbed by the stars in whose neighbourhood it is found to furnish, by its condensation, their supply of light and heat? or is it progressively concentrating itself by the effect of its own gravity into masses, and so laying the foundation of new sidereal systems or of insulated stars? *It is easier to propound such questions than to offer any probable reply to them.* Meanwhile, appeal to fact, by the method of constant and diligent observation, is open to us; and as the double stars have yielded to this style of questioning, and disclosed a series of relations of the most intelligible and interesting description, we may reasonably hope that the assiduous study of the nebulæ will ere long lead to some clearer understanding of their intimate nature."

On the whole, the nebulæ, whether resolvable or irresolvable, open to view an inexhaustible field of contemplation and wonder. By far the greater part of the nebulæ are undoubtedly clusters of stars, some of them perhaps containing as many millions as our Milky Way, and occupying a space in the tracts of immensity which imagination can never fathom; but a considerable proportion of these bodies evidently appear to be masses of self-luminous substances, without any indication of being formed into organized systems; and how enormous must be the extent of most of those masses, and how vast the regions of space which they fill! If every one of those bodies be only one-half the size of the great nebula in Orion, what a prodigious mass of matter must they contain, and what an immense space must hundreds and thousands of them occupy! To limited minds such as ours, such spaces appear as approximating to *infinity*, and all our previous ideas of the amplitude of planetary systems sink into something approaching to inanity. Whatever purposes these immense masses of matter may serve under the administration of Infinite Wisdom, certain it is *they exist not in vain*. They accomplish designs worthy of the plans of Divine Intelligence, and have doubtless a relation, in one respect or another. to the enjoyments of intelligent beings; but the full developement of the plans and agencies of the Deity in this and in many other parts of the economy of the universe, must be considered as reserved for another and a future scene of existence.

## Section VI.

### *List of some of the Larger Nebulæ.*

For the sake of those who wish to inspect some of the nebulous bodies by means of telescopes, I have subjoined the following list from Messier's Catalogue, along with the more recent observations of Sir W. Herschel. The right ascensions and declinations are given in degrees and minutes, by which the places of these bodies may be very nearly found on a celestial globe. If it be judged expedient to reduce the degrees and minutes of right ascension to *time*, it may be done by the following rules:—Divide the number of degrees by 15, the quotient is hours; and the remainder reduced to minutes and divided by

15, gives the minutes, &c. of time: or, multiply the given number of degrees and minutes by 4, and divide the degrees in the product by 60, the quotient is hours, and the remainder minutes, &c. Thus, 320° 17′ is equal to 21 hours, 21 minutes, and 8 seconds of time.

In the following list, R. A. means right ascension; dec., declination; S., south; N., north; diam., diameter of the object, which is expressed in minutes of a degree.

1. R.A. 80° 0′ 33″; dec. N. 21° 45′ 27″; above the Bull's southern horn west of the star ζ: this consists of a whitish light, elongated like the flame of a taper: it exhibited a mottled nebulosity to Sir W. Herschel.
2. R.A. 320° 17′; dec. S. 1° 47′; diam. 4′; in the head of Aquarius, near the 24th star: it appears like the nucleus of a comet, surrounded with a large round nebula: Sir W. Herschel resolved it into stars.
3. R.A. 202° 51′ 19″; dec. N. 29° 32′ 57″; diam. 3′; between Arcturus and Cor Caroli: it is round, bright in the centre, and fades away gradually: it exhibited a mottled nebulosity to Sir W. Herschel.
4. R.A. 242° 16′ 26″; dec. S. 25° 55′ 40″; diam, 2½′; near *Antares*: a mass of stars.
5. R.A. 226° 39′; dec. N. 2° 57′; diam. 3′; near 6 Seppent: a round nebula, resolved into stars by Sir W. Herschel.
6. R.A. 261° 10′ 39″; dec. S. 32° 10′ 34″; diam. 15′; between the bow of Sagittarius and the tail of Scorpio: a mass of small stars.
7. R.A. 264° 30′ 24″; dec. S. 34° 40′ 34″; diam. 30′: a mass of small stars near the preceding.
8. R.A. 267° 29′ 30″; dec. S. 24° 21′; diam. 30′; between the bow of Sagittarius and the right foot of Ophiuchus: an elongated mass of stars. Near this mass is the 9th of Sagittarius, which is encircled with a faint light.
9. R.A. 256° 20½′; dec. S. 18° 13′ 26″; diam. 3′; in the right leg of Ophiuchus: round and faint, but resolved by Sir W. Herschel into stars.
10. R.A. 251° 12′ 6″; dec. S. 30° 42′; diam. 4′; in the girdle near 30 Ophiuchus: a fine and round nebula, resolved into stars by Sir W. Herschel.
11. R.A. 279° 35′ 43″; dec. S. 6° 31′; diam. 4′; near K Antinous: a mass of many stars, mixed with a faint light.
12. R.A. 248° 43′; dec. S. 2° 30½′; diam. 3′; between the arm and left side of Ophiuchus: round and faint. near it is a star of the ninth magnitude: resolved into stars by Sir W. Herschel.
13. R.A. 248° 18′ 48″; dec. N. 36° 54′ 44″; diam. 6′; in the girdle of Hercules, between two stars of the eighth magnitude: round, and bright in the middle, resolved into stars by Sir W. Herschel.
14. R.A. 261° 18½′; dec. S. 3° 5′ 45″; diam. 7′; in the drapery over the right arm of Ophiuchus: round and faint: near a star of the ninth magnitude: resolved into stars by Sir W. Herschel.
15. R.A. 319° 40′; dec. N. 10° 40′; diam. 3′; between the head of Pegasus and that of the Little Horse: round, and bright in the centre, resolved into stars by Sir W. Herschel.
16. R.A. 271° 15′; dec. N. 13° 51′ 44″; diam. 8′; near the Serpent's tail; a mass of small stars, mixed with a faint light, resolved by Sir W. Herschel.
17. R.A. 271° 45′ 48″; dec. S. 16° 14′ 44″; diam. 5′; north of the bow of Sagittarius: a train of faint light, with stars.
18. R.A. 271° 34′; dec. S. 17° 13′; diam. 5′; above the preceding: a mass of small stars, surrounded with nebulosity.
19. R.A. 252° 1′ 45″; dec. S. 25° 54′ 46″; diam. 3′; between Scorpio and the right foot of Ophiuchus: round, and resolved into stars by Sir W. Herschel.
20. R.A. 267° 4′ 5″; dec. S. 22° 59′ 10″; between the bow of Sagittarius and right foot of Ophiuchus: a mass of stars of the eighth and ninth magnitudes, surrounded with nebulosity.
21. R.A. 267° 31′ 35″; dec. S. 22° 31′ 25″; diam. 6′; near 11 Sagittarius: similar to the preceding.
22. R.A. 275° 28′ 39″; dec. S. 24° 6′ 11″; diam. 15′; near 25 Sagittarius: round, and resolved into stars by Sir W. Herschel.
23. R.A. 265° 42′ 50″; dec. S. 18° 45′ 55″; diam. 1° 30′; near 65 Ophiuchus. a mass of stars very near each other.
24. R.A. 270° 26′; dec. S. 18° 26′; near end of the bow of Sagittarius in the Milky Way: great nebulosity containing several stars, the light is divided into several parts.
25. R.A. 274° 25′; dec. S. 19° 5′; diam. 10′; near preceding, near 21 Sagittarius: a mass of small stars.
26. R.A. 278° 5′ 22″; dec. S. 9° 38′ 14″; diam. 2′; near n and o Antinous: a mass of small stars.
27. R.A. 237° 21′ 41″; dec. N. 22° 4′; diam. 4′; near 14 of the Fox: oval:

it exhibited a mottled nebulosity to Sir W. Herschel.

28. R.A. 272° 29½′; dec. S. 24° 57′; diam. 2′; a degree from λ Sagittarius: round, and resolved into stars by Sir W. Herschel.

29. R.A. 303° 54½′; dec. N. 37° 12′; below γ Cygni: a mass of seven or eight small stars.

30. R.A. 321° 46′; dec. S. 24° 19′; diam. 2′; near 41 Capricorn: round, and resolved into stars by Sir W. Herschel.

31. R.A. 7° 26½′; dec. N. 39° 9½′; diam. 40′; in Andromeda's girdle: it resembles two cones of light joined at their base, which is 15′ broad: resolved into stars by Sir W. Herschel.

32. R.A. 7° 27½′; dec. N. 38° 45½′; diam. 2′; below the preceding: round, without stars, and with a faint light.

33. R.A. 20° 9′; dec. N. 29° 32½′; diam. 15′; below the head of the North Fish and the Great Triangle: its light is uniform and whitish: it exhibited a mottled nebulosity to Sir W. Herschel.

34 R.A. 36° 51½′; dec. N. 41° 39½′; diam. 15′; between Medusa's head and the left foot of Andromeda: a mass of small stars.

35. R.A. 88° 40′; dec. N. 24° 33½′; diam. 20′; near μ and ν Castor: a mass of small stars near Castor's left foot.

36. R.A. 80° 11′ 42″; dec. N. 34° 8′ 6″; diam. 9′; near φ Bootes: a mass of small stars.

37. R.A. 84° 15′; dec. N. 32° 12′; near the preceding: a mass of small stars, with a nebulosity, resolved into stars by Sir W. Herschel.

38. R.A. 78° 10′; dec. N. 36° 12′; near σ Aurigæ: a square mass of stars.

39. R.A. 320° 57′; dec. N. 47° 25′; diam. 15′; near the Swan's tail: a mass of small stars.

40. R.A. 182° 45½′; dec. N. 59° 24′; diam. 1°; at the root of the Great Bear's tail: two stars, very near each other.

41. R.A. 98° 58′; dec. S. 20° 33′; below Sirius: a mass of small stars.

42. R.A. 80° 59′ 40″; dec. S. 5° 34′ 6″; diam. 6′; between θ and c in Orion's sword: a beautiful nebula containing seven small stars.

43. R.A. 81° 3′; dec. S. 5° 26′ 37″; above the preceding: a star surrounded with nebulosity.

44. R.A. 126° 50½′; dec. S. 20° 31½′; between γ and δ Cancer: a mass of small stars.

45. R.A. 53° 27′ 4″; dec. N. 23° 22′ 41″; the Pleiades: a cluster of stars.

46. R.A. 112° 47′ 43″; dec. S. 14° 19′; between the Great Dog's head, and the hind feet of the Unicorn: a mass of stars with a little nebulosity.

47. R.A. 116° 4′; dec. S. 14° 50′; near the preceding: a mass of small stars.

48. R.A. 120° 36′; dec. S. 1° 16′ 42″; near the three stars at the root of Unicorn's tail: a mass of small stars.

49. R.A. 184° 26′ 58″; dec. N. 9° 16′ 9″; near ρ Virgo.

50. R. A. 102° 57½′; dec. S. 7° 57′ 42″; above θ Great Dog: a mass of small stars below Unicorn's right thigh.

51. R.A. 200° 5′ 48″; dec. N. 48° 24′ 24″; below η Great Bear, near the ear of the Northern Grayhound: double: the two atmospheres, whose centres are 4′ 35″ distant, touch one another, and are bright in the middle; the one is fainter than the other: resolved into stars by Sir W. Herschel.

52. R.A. 348° 39½′; dec. N. 60′ 22″; below *d* Cassiopeia: a mass of stars mixed with a nebulosity, according to Sir W. Herschel: this cluster appears like a solid ball, consisting of small stars, quite compressed into one blaze of light, with a great number of loose ones surrounding it.

53. R.A. 195° 30½′; dec. N 19° 22′ 44″; near 42 Berēnice's hair: round, and resolved into stars by Sir W. Herschel.

54. R.A. 280° 13′; dec. S. 30° 44′; diam. 6′; in Sagittarius: faint, and bright in the centre.

55. R.A. 291° 30½′; dec. S. 31° 26½′; in Sagittarius: a white spot, resolved into stars by Sir W. Herschel.

56. R.A. 287°; dec N. 29° 48′; near the Milky Way, faint, resolved into stars by Sir W. Herschel.

57. R.A. 281° 20′; dec. N. 32° 46′; between γ and β Lyræ: round, and consisting of a mottled nebulosity.

58. R.A. 136° 37½′; dec. N. 13° 2′ 42″; in Virgo: very faint, without any star.

59. R.A. 187° 41′ 38″; dec. N. 12° 52½′; near the preceding: very faint, without any star.

60. R.A. 188° 7′; dec. N. 12° 46′; in Virgo: brighter than the two preceding.

61. R.A. 182° 41′; dec. N. 5° 12′; in Virgo: very faint.

62. R.A. 251° 48½′; dec. S. 29° 45½′; in Scorpio: like a comet, with a brilliant centre surrounded with a faint light; resolved into stars by Sir W. Herschel.

63. R.A. 196° 5½′; dec. N. 43° 12½′; in the Canes Venatici: very faint.

64. R.A. 191° 27′ 38″; dec. N. 22° 52½′, in Berenice's hair: faint.

65. R.A. 166° 51′; dec. N. 14° 16′; in the

Lion: faint, but resolved into stars by Sir W. Herschel.

66. R.A. 167° 11′ 39″; dec. N. 14° 12′ 21″; very near the preceding: very faint, but resolved into stars by Sir W. Herschel.

67. R.A. 129° 7′; dec. N. 12° 36′ 38″; below the northern claw of the Crab: a mass of stars with nebulosity. It is a cluster pretty much compressed, in which Sir W. Herschel has observed 200 stars at once with a power of 157. (See p. 79.)

68. R.A. 186° 54½′; dec. S. 25° 30½′; diam. 2′; below the Crow, very faint.

69. R.A. 274° 11′ 46″; dec. S. 32° 31′ 45″; diam. 2′; below the left arm of Sagittarius: faint, like the nucleus of a small comet.

70. R.A. 277° 13′; dec. S. 32° 31′; diam. 2′; near the preceding, near four telescopic stars.

71. R.A. 295° 59′ 9″; dec. N. 18° 13′; diam. 3′ 30″; between $\gamma$ and $\delta$ of the Arrow: very faint, and resolved into stars by Sir W. Herschel.

72. R.A. 310° 20′ 49″; dec. S. 13° 20′ 51″; diam. 2′; above the tail of Capricorn: faint, but resolved into stars by Sir W. Herschel.

73. R.A. 311° 43′; dec. S. 13° 28′ 40″ near the preceding: three or four small stars, containing a little nebulosity.

74. R.A. 21° 14′; dec. N. 15° 39′ 35″ near $\eta$ in the string that connects the Fishes: very faint, but resolved into stars by Sir W. Herschel.

75. R.A. 298° 17′ 24″; dec. S. 22° 32′ 23″; between Sagittarius and the head of Capricorn: composed of small stars with nebulosity. The astronomer Mechain makes it only nebulous.

76. R.A. 22° 10′ 47″; dec. N. 50° 28′ 48″; diam. 2′; in Andromeda's right foot: composed of small stars with nebulosity, small and faint.

77. R.A. 37° 52½′; dec. S. 57′ 43″; in the Whale: a mass of stars containing nebulosity.

78. R.A. 83° 53½′; dec. S. 1′ 23″; diam. 3′; in Orion: a mass of stars with two bright nuclei, surrounded with a nebulosity.

79. R.A. 78° 49′; dec. S. 24° 43″; below the Hare: a fine nebula, bright in the centre, and a little diffused, resolved into a mottled nebulosity by Sir W. Herschel.

80. R.A. 241°; dec. S. 22° 25′; diam. 2′; between $y$ and $\delta$ Scorpio: round, and bright in the centre, like a comet.

81. R.A. 144° 27′ 44″; dec. N. 70° 7′ 24″; near the ear of the Great Bear: a little oval, bright in the centre, and exhibiting a mottled nebulosity to Sir W. Herschel.

82. R.A. 144° 29′ 22″; dec. N. 70° 44′ 27″; near the preceding: faint and elongated, with a telescopic star at its extremity; it showed a mottled nebulosity to Sir W. Herschel.

83. R.A. 201° 8′; dec. S. 28° 42½′; near the head of the Centaur: very faint.

84. R.A. 183° 30½′; dec. N. 14° 7′; in Virgo: bright in the centre, and surrounded with nebulosity.

85. R.A. 183° 35′ 21″; dec. N. 19° 24½′; above and near Spica: very faint.

86. R.A. 183° 46′ 21″; dec. 14° 10′; in Virgo: the same as No. 84, and near it.

87. R.A. 184° 56′; dec. N. 13° 38′; in Virgo: as luminous as the preceding.

88. R.A. 185° 16′; dec. N. 15° 38′; in Virgo: very faint, and like No. 58.

89. R.A. 186° 9′ 36″; dec. N. 13° 46′ 49″; near No. 87: very faint.

90. R.A. 186° 27′; dec. N. 14° 23′; in Virgo: very faint.

91. R.A. 186° 37′; dec. N. 14° 57′; above the preceding: fainter than the preceding.

92. R.A. 257° 38′; dec. N. 43° 22′; diam. 5′; between the knee and left leg of Hercules; a beautiful nebula, bright in the centre, and surrounded with great nebulosity: resolved into stars by Sir W. Herschel.

93. R.A. 113° 48′ 35″; dec. S. 23° 19′ 45″; diam. 8′; between the Great Dog and Ship: a mass of small sta[illegible]

94. R.A. 190° 10′ 46″; dec. N. 42° [illegible], diam. 2½′; above Cor Caroli: bright in the centre, with a diffused nebulosity.

95. R.A. 158° 3′ 5″; dec. N. 12° 50′ 21″; in the Lion, above $l$: very faint.

96. R.A. 158° 46½′; dec. N. 12° 58′; near the preceding: fainter than the preceding.

97. R.A. 165° 18′ 40″; dec. N. 56° 13½′; diam. 2′; near $\beta$ Great Bear: very faint: another near it, and and another near $\gamma$.

98. R.A. 180° 50′ 49″; dec. N. 16° 8′ 15″; above the north wing of Virgo: very faint.

99. R.A. 181° 55′ 19″; dec. N. 15° 37′ 12″; on the north wing of Virgo: brighter than the preceding: between two stars of the seventh and eighth magnitude.

100. R.A. 182° 59′ 19″; dec. N. 16° 59′ 21″; in the ear of corn of Virgo: brighter than No. 98.

101. R.A. 208° 52′; dec. N. 55° 24′ 25″; diam. 7′; between the left hand of Bootes and the tail of the Great Bear: very faint: discovered by Mechain: mottled nebulosity, according to Sir W. Herschel.

102. Between $o$ Bootes and $\iota$ Draconis: very faint: discovered by Mechain.

103. Between $\varepsilon$ and $\delta$ Cassiopeia: a mass of stars.

## CHAPTER XIII.

### *On the Aberration of the Stars, and on their Proper Motions.*

The aberration of the fixed stars is a small change of place in the heavens which they seem to undergo, and by which they appear to describe, in the course of a year, an ellipsis or circle, the greatest diameter of which is about forty seconds. This remarkable fact was discovered, near the middle of the last century, by the celebrated Dr. Bradley, formerly Regius Professor of Astronomy at Greenwich.

In Chapter IV., when describing the mode of finding the parallaxes of the fixed stars, I have given a brief detail of the circumstances which led to this discovery, and the observations from which the aberration of the stars was deduced. Before perusing the following illustrations of this subject, it may not be improper for the reader to reperuse what was there stated in reference to this point, particularly the illustration of this phenomenon given in the description of Fig. 7, (p. 34, 35.) It is there stated that Dr. Bradley and his friend Mr. Molyneux were very much perplexed at the result of their observations; since, instead of observing a motion indicating an annual parallax, they found a result directly opposite to what they expected. Many theories and conjectures were proposed to solve the appearances, but nothing satisfactory was elicited, till one day, when Dr. Bradley was enjoying the amusement of sailing about on the Thames, he observed that every time the boat tacked, the direction of the wind, estimated by the direction of the vane, seemed to change. This immediately suggested to him the cause of the phenomenon which had so much perplexed him, and he ultimately found it to be an optical illusion occasioned by a combination of the motion of light with the motion of his telescope while observing the polar stars—a discovery of no inconsiderable importance, and which will immortalize the name of this sagacious and indefatigable astronomer. He perceived that, if light is propagated in time, the apparent place of a fixed object will not be the same when the eye is at rest, as when it is moving in any other direction than that of the line passing through the eye and the object; and that, when the eye is moving in different directions, the apparent place of the object will be different.

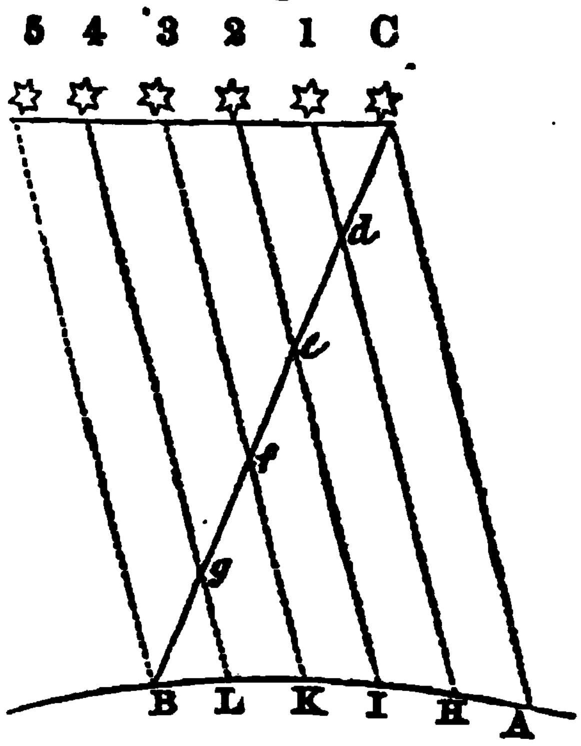
We see an object in consequence of the rays of light proceeding from it striking our eyes, and we see the place of the object *in the direction in which they proceed.* If light be in motion and the eye at rest, the object will appear in its real place, provided no refracting medium intervene; but if the eye be in motion, and this motion in a different direction from that of the rays of light, the object will not be seen in its true position. Let us suppose the earth in its circuit round the sun just arrived opposite to a fixed star, which sends off rays *perpendicularly* to the direction of the earth's motion. The eye of the spectator meets the ray, and, as he perceives not his own motion, he supposes the light to be moving in a different direction; as when we sail along a winding river, certain objects on the banks appear to pass us in different directions. The eye misses the perpendicular ray, but meets an oblique one, and thence receives the impression of the light in the direction which results from this compound motion—namely, in the diagonal of a parallelogram, the sides of which represent the real motion of light. The spectator sees the star in its true place only when he is approaching it or receding from it in a straight line. When moving in any other direction, the star appears a little in advance of its true position; and these apparent changes in the situation of the heavenly bodies, occasioned by the annual motion of the earth, are distinguished by the *aberration of light.* They are common, to a certain extent, to all the celestial orbs, and are only more perceptible and striking in the case of the fixed stars. In consequence of this aberration during the revolution of the earth round the sun, the stars appear, according as they are situated in the plane of the ecliptic, or in its poles, or somewhere between them, in the first case, to deviate in a straight line to the right or left of their true place; in the second, to describe a circle, or something nearly approximating to it; and in the third, an ellipse about that point which observation determines to be their real situation.

This subject requires a little degree of attention in order to a clear understanding of it. Perhaps the following illustrations may, in some measure, render it plain to the general reader.

Suppose *A B*, in the following figure, to represent a part of the orbit of the earth, and

$C\,B$ a ray of light descending from a star upon the earth's orbit, $A\,B$; if the eye be at

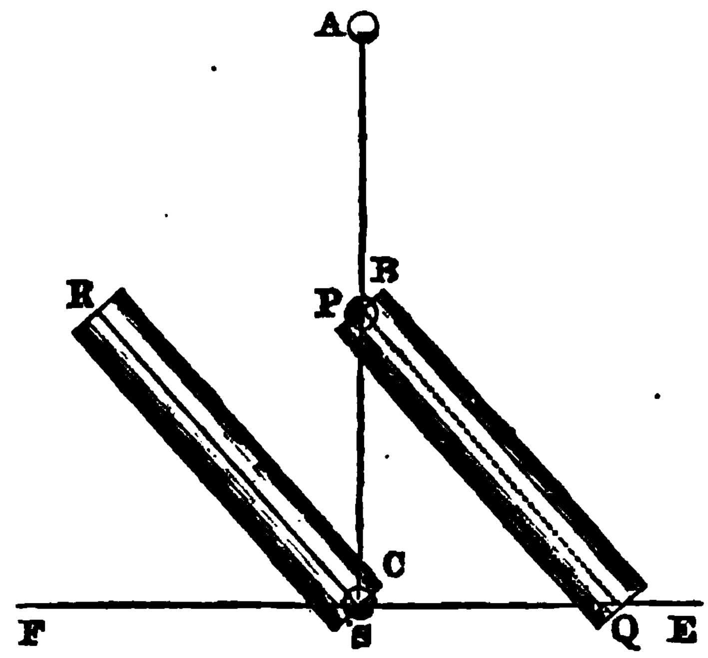
Fig. 74.




rest at $B$, the object will appear in the direction $B\,C$; but if the eye be moving from $A$ towards $B$, and light be propagated with a velocity that is to the velocity of the eye (or of the earth's motion) as $C\,B$ to $B\,A$, that particle of it, by which the object will be discerned when the eye comes to $B$ will be at $C$ when the eye is at $A$; the star, therefore, will appear in the direction $A\,C$; and as the earth moves through the equal parts of its orbit, $A\,H$, $H\,I$, $I\,K$, &c., the light coming from the star will move through the equal divisions $C\,d$, $d\,e$, $e\,f$, $f\,g$, $g\,B$, and the star will appear successively in the directions $H\,1$, $I\,2$, $K\,3$, $L\,4$, $B\,5$, which are parallel to $A\,C$; so that when the eye comes to $B$, the object will be seen in the direction $B\,5$.

The following is an explanation of this phenomenon as given by Sir John Herschel. Suppose a shower of rain to fall perpendicularly in a dead calm; a person exposed to the shower who should stand quite still and upright would receive the drops on his hat, which would thus shelter him; but if he ran forward in any direction they would strike him in the face. The effect would be the same as if he remained still, and a wind should arise of the same velocity and drift them against him. Suppose a ball to fall from a point $A$ (fig. 75) above a horizontal line $E\,F$, and that at $B$ were placed to receive it the open mouth of an inclined hollow tube $P\,Q$; if the tube were held immovable, the ball would strike on its lower side; but if the tube were carried forward in the direction $E\,F$ with a velocity properly adjusted at every instant to that of the ball, *while preserving its inclination to the horizon*, so that when the ball in its natural descent reached $C$, the tube should have been carried into the position $R\,S$, it is evident that the ball would, throughout its whole descent, be found in the axis of the tube; and a spectator, referring to the tube the motion

Fig. 75.




of the ball, and carried along with the former unconscious of its motion, would fancy that the ball had been moving in the inclined direction $R\,S$ of the tube's axis. Our eyes and telescopes are such tubes. The earth is moving through space with a velocity of nineteen miles per second in an elliptic path round the sun, and is therefore changing the direction of its motion at every instant. Light travels with a velocity of 192,000 miles per second, which, although much greater than that of the earth, is yet not *infinitely so*. Time is occupied by it in traversing any space, and in that time the earth describes a space, which is to the former as 19 to 192,000, or as the tangent of $20''.5$ to radius. Suppose, now, $A\,P\,S$ to represent a ray of light from a star at $A$, and let the tube, $P\,Q$, be that of a telescope so inclined forward that the focus *formed* by its object glass shall be *received* upon its cross wire, it is evident, from what has been said, that the inclination of the tube must be such as to make $P\,S : S\,Q ::$ velocity of light : velocity of the earth :: tangent $20\frac{1}{2}''$ : 1; and therefore the angle $S\,P\,Q$, or $P\,S\,R$, by which the axis of the telescope must deviate from the true direction of the star, must be $20\frac{1}{2}''$.

The aberration of the stars has also been illustrated by the direction in which a gunner points his gun at a bird on the wing. Instead of levelling it exactly at the bird, he directs it a little before the bird in the path of its flight, and so much the more in proportion as the flight of the bird is more rapid compared with that of the shot. It may likewise be explained by supposing a person to be walking in a shower of rain with a narrow tube in his hand, in which case it is evident that the tube must have a certain inclination, so that a drop of rain which enters at the top may fall freely

through it without touching its sides; which inclination must be greater or less according to the velocity of the drops with respect to the tube.

From the discovery of the aberration of the stars the following conclusions, among others, have been deduced,—1. That the small apparent motion which the fixed stars have about their real places, arises from the proportion which the velocity of the earth's motion in its orbit bears to that of light. This proportion is found to be as 1 to 10,310; or, in other words, light moves with a velocity ten thousand three hundred and ten times greater than that of the earth in its annual course round the sun.* 2. From this discovery it is proved that *the velocity of light is uniform* and the same, whether as emitted originally from the sun and stars, or reflected from the planets. The velocity of the earth in its orbit is about 68,000 miles an hour; consequently, the motion of light in the same time is 701,080,000, or a little more than seven hundred millions, which gives about eight minutes and eight seconds as the time it will take in passing from the sun to the earth.† This is about the same rate of the motion of light as first determined by Roemer from the eclipses of Jupiter's satellites; so that the two discoveries mutually harmonize and confirm each other, and prove to a demonstration the progressive motion of light, and that its rate of motion is the same whether as emanating from the sun, reflected from the satellites of Jupiter, or descending from the stars. 3. The aberration of light affects the apparent right ascensions and declinations of all the stars. Its effect on each particular star is to make it apparently describe a small ellipse in the heavens, having for its centre the point in which the star would be seen if the earth were at rest. Hence, in all very nice calculations and determinations of the positions of the stars, allowance must be made for the effects produced by aberration. 3. The aberration of light *affords a sensible and direct proof of the motion of the earth* in its orbit round the sun. If the earth were not in motion, no such effect as that of the aberration of the stars could take place. If the earth were at rest, rays from a star would pass along the axis of a telescope directed to it, but were it set in motion with its present velocity, these rays would strike against the side of the tube, and it would be necessary to incline the telescope a little in order to see the star. The angle contained between the axis of the telescope and a line drawn to the true place of the star is just what we call its *aberration*, which could not take place if the earth were not in motion. That the earth is a planetary body moving through the depths of space along with the other planets of our system can be proved by numerous considerations; but the fact of the aberration of the stars exhibits this motion to our senses as clearly as if from a fixed point in the firmament we actually beheld it pursuing its course through the ethereal regions; so that the planetary nature of our globe, and the truth of the Copernican system, are no longer to be considered as mere hypotheses, but as facts susceptible of the strictest demonstration.

### *On the Proper Motion of the Stars.*

To the eye of a common observer, all the stars and constellations in the heavens appear to preserve the same relative distances from each other; and even astronomers, not more than two centuries ago could perceive no separate motions or variations in the positions of these distant orbs. From this circumstance they were denominated *fixed stars*, to distinguish them from the *planets*, which were observed to shift their positions, and to move through different parts of the heavens. After the telescope was invented and applied to astronomical instruments, astronomers began to suspect that some of the stars had a slight degree of proper motion or change in their relative position, but it was a considerable time before such motions could be distinctly ascertained. These motions first began to be observed by Dr. Halley, and afterwards by Lemonnier and Cassini, and were completely confirmed by Tobias Mayer, who compared the places of eighty stars as determined by Roemer with his own observations, and found that the greater part of them had a proper motion. He likewise suggested that the change of place he had observed among these stars might arise from a progressive motion of the sun towards one quarter of the heavens. La Lande deduced a similar opinion from the rotary motion of the sun, by supposing that the same mechanical force which gave it a motion round its axis, would also displace its centre, and give it a motion of translation in absolute space. Of the same opinion was Sir

* This is the proportion of radius to the tangent of twenty seconds and a half, which is the greatest apparent displacement of the star caused by aberration, and the radius of the circle described by the star round its real place in the course of a year.

† This is found by multiplying 10,310 — the number of times that the velocity of light exceeds that of the earth, by 68,000 — the rate of the earth's motion in an hour; the product is 701,080,000. This product divided by 60 gives the rate of motion in a minute = 11,684,666. Divide 95,000,000, the distance of the sun from the earth, by this last number, and the quotient will give eight minutes and nearly eight seconds as the time light should take in passing from the sun to the earth.

W. Herschel, and he attempted, by a comparison of the proper motions of all the stars that had been ascertained, to determine the point of the heavens towards which the motion of the sun was directed, which he supposed was that occupied by the star *Zeta* Herculis.

If the sun really have a motion in absolute space directed towards any particular quarter of the heavens, it is obvious that the stars in that quarter must appear to recede from each other, while those in the opposite region, which the sun is leaving behind, must seem gradually to approach, in the same manner as when we walk through a forest, the ranges of trees to which we advance are constantly widening in their apparent distance from each other, while the distance of those we leave behind is gradually contracting. It does not, however, appear, from the most recent observations, that the direction in which the sun or planetary system is moving is yet determined, although it is admitted that our system has a motion in space, and that the apparent proper motions of *some* of the stars *may be* the result of our being carried in a certain direction through absolute space by this motion. Such a motion, and even the direction of it, might be detected by such sidereal observations as those to which we allude, if we knew accurately the apparent proper motions of those bodies, and that they were independent of any *general motions* common to all the stars; but in the present stage of sidereal observation, it seems to be the general opinion of the most eminent astronomers, that no sufficient data are yet afforded for deducing definite conclusions on this subject.

The following table contains a few specimens of the annual proper motions of the stars in right ascension and declination, in seconds and decimals of a second, selected from the observations of Dr. Maskelyne. The first column contains the name of the star; the second, its magnitude; the third, its annual proper motion in right ascension; and the fourth, its motion in declination.

| Names of the Stars. | Magnitude. | Annual Motion in R. A. | Annual Motion in Dec. |
|---|---|---|---|
| | | Seconds. | Seconds. |
| Capella | 1 | + 0.21 | + 0.44 N. |
| Sirius | 1 | — 0.42 | + 1.04 S. |
| Castor | 1 | — 0.15 | + 0.44 S. |
| Procyon | 1.2 | — 0.80 | + 0.95 S. |
| Pollux | 2 | — 0.74 | 0.00 |
| $\beta$ Leonis | 1.2 | — 0.57 | + 0 07 S. |
| $\beta$ Virginis | 3 | + 0.74 | + 0.24 S. |
| Arcturus | 1 | — 1.26 | + 1.72 S. |
| Altair | 1.2 | + 0.48 | — 0.54 N. |
| $\alpha$ Lyræ | 1 | + 0.23 | — 0.27 N. |
| Antares | 1 | 0.00 | — 0 26 N. |

In the above table, the sign + prefixed to the annual variation of right ascension indicates that the variation is to be *added* to, and the sign — that it is to be *subtracted* from, the right ascension, to obtain the true place of the object at any given time.

It is found that not only among single, but even among *double* stars such motions exist. While revolving round each other in the manner formerly described, they are at the same time carried forward through space with a progressive motion common to both, and without sensibly altering their distances from each other. One of the most remarkable of these is the double star 61 Cygni, formerly described, whose annual parallax and distance Professor Bessel appears to have lately determined.* The two stars of which it is composed are nearly equal in apparent size, and they have remained constantly at the same distance of 15 seconds for at least fifty-seven years past, or since their positions began to be accurately observed. The annual proper motion of these two stars is found to be, according to Bessel, 5″.123; which is the greatest annual proper motion of any of the stars which has yet been discovered; consequently, during the period now mentioned, they must have shifted their local situation in the heavens by a space equal to 4 minutes, 52 seconds; that is, a space equal to more than one-seventh of the apparent diameter of the moon. Such a change of place in bodies so immensely distant as 62,000,000,000,000 of miles indicates a prodigious rapidity of motion. "The relative motion of these stars and the sun," says Bessel, "must be considerably more than sixteen† semi-diameters of the earth's orbit;" that is, 1,552,000,000 of miles. They must therefore move at the rate of four millions two hundred and fifty-two thousand miles a day, and one hundred and seventy-seven thousand miles every hour; which is 68,000 miles an hour greater than the velocity of Mercury, which is the swiftest moving body in the planetary system. Here, then, we have a system of bodies of immense size moving with amazing velocity in different directions; for as these stars are doubtless suns, and consequently have a system of planets revolving round each, the planets must move round the sun to which they more immediately belong, and likewise round the other sun, or their common centre of gravity, and at the same time they are carried forward to some distant region with the velocity now stated.

Among single stars, that which is marked $\mu$ Cassiopeia, one of the smaller stars in that constellation, is marked as having the greatest proper motion of any yet ascertained. The amount of its annual motion is estimated at 3¾ seconds, which in the course of a century will amount to 6 minutes 15 seconds, a space

* See chap iv. p. 37, &c.
† About 16¼. See p. 38.

in the heavens equal to one-fifth of the apparent diameter of the moon. If this star be reckoned at the same distance from the earth as the double star 61 Cygni, the velocity of its motion every day will be 3,112,000 miles; every hour, 130,000; and every minute, 2,160. The annual proper motion of Arcturus, in declination, is $1''.72$, which is nearly one-half the motion of $\mu$ Cassiopeia; and a great many others are found by observation to be constantly progressing through the heavens by annual intervals of different degrees in extent, but generally smaller than those stated above. These changes of position in the stars cannot be perceived by the naked eye, and are consequently imperceptible to common observers; and even with the most accurate astronomical instruments some of them cannot be determined until after a lapse of years. Such motions give us reason to conclude that all the bodies in the universe are in perpetual motion, and many of them acted upon by separate forces, which carry them in different directions; and although some of these motions appear little more than just perceptible at the immense distance at which we are placed from them, yet it is probable that even the slowest motion of any of the stars is not less than at the rate of several thousands of miles every hour, indicating the operation of forces incomprehensible by the human mind.

## CHAPTER XIV.

### *On the Destination of the Stars; or, the designs they are intended to subserve in the System of the Universe.*

For many ages during the infancy of astronomy, the stars were considered chiefly as an appendage to the world in which we dwell. The crystalline sphere in which they were supposed to be fixed was regarded as only the canopy of man's terrestrial habitation, and the orbs with which it is diversified as so many brilliant spangles to adorn it, and to diffuse a few glimmering rays to cheer the darkness of the night. This celestial arch, in which the sun and moon are also placed, was supposed to revolve around us every twenty-four hours, producing an alternate succession of light and of darkness, while the earth, as the centre of the universe, was considered as remaining in a state of perpetual quiescence. Above the visible heavens, where the stars are placed, nothing was supposed to exist except the throne of the Almighty and the abodes of the blessed; and such are still the contracted views of the majority of the inhabitants of our globe respecting that immense and glorious firmament with which we are surrounded.

It is true indeed that the stars, in a certain subordinate sense, were intended for the benefit of man; for we actually derive many advantages from their apparent motions and influence. They present to our view a scene of beauty and magnificence which enchants the eye and gratifies the imagination, and tends to raise the soul above grovelling pursuits and terrestrial vanities. They cheer the shades of midnight and enable us to prosecute our journeys after the sun has left our hemisphere; without the influence of whose light our winter evenings would be shrouded in impenetrable darkness, and not an object around us could be distinguished. In the absence of the moon all would be dark, as was chaos before light was formed to illuminate creation. Were the light of the starry orbs extinguished, instead of the grand and beautiful aspect now presented from above, the firmament would appear only like an immense blank, or a boundless desert, where nothing would be seen to stimulate human inquiry, or to display the attributes of the Creator. Those orbs are likewise of essential service to different departments of human life; they serve as guides to the traveller when journeying through vast and unfrequented desarts, and to the mariner when conducting his vessel from one country to another through the wide and pathless ocean. The Pole-star, on account of its apparently fixed position, has in every age been viewed with solicitous attention by the navigator; and before the invention of the compass it was his principal guide to direct his bark to the desired haven. In short, by means of the stars we have been enabled to determine the exact length of the day and of the year, the various subdivisions of time, the commencement and termination of the seasons, the circumference of the globe, the density of its materials, and the relative positions of places on every part of its surface; all which advantages it becomes man duly to appreciate, and with a grateful heart to adore the wisdom and goodness of Him "who made the sun to rule the day and the moon and stars to rule the night," and who has rendered all his arrangements subservient to the happiness of his intelligent offspring.

But although the stars are of essential

benefit to the inhabitants of our globe, yet we ought not for a moment to imagine that this was the chief and ultimate end for which they were brought into existence. We know that they are bodies of immense size, the least of them many thousands of times larger than our globe. But such a number of magnificent globes were not necessary, in order to shed a few glimmering rays upon the earth; since the creation of an additional moon would diffuse far more light over our world than that which descends to the earth from all the visible stars in the firmament. And we know that the Creator does nothing in vain. It is the characteristic of infinite wisdom to proportionate means to the end intended to be accomplished; but in this case there would be no proportion between the means and the end—between creating a thousand globes of light of incalculable magnitude, and shedding a few glimmering rays to alleviate the darkness of midnight; and therefore this cannot be supposed the chief end of their creation, without impeaching the wisdom and intelligence of Him "who stretched out the heavens by his understanding." Besides, whatever might be said in reference to the stars visible to the unassisted eye, it is impossible for a moment to conceive that those thousands, and ten thousands, and millions of stars, which are only visible through the most powerful telescopes, and whose light has never yet reached our globe, could have been created merely for the use of the inhabitants of this earth. Such a supposition must be for ever discarded by every one who would entertain an honourable and consistent idea of the operations of infinite wisdom.

What, then, it may be asked, is the chief and ultimate destination of those magnificent globes? We may answer in general terms, that it is a destination corresponding to the magnitude and grandeur, and the intrinsic splendour of those distant bodies. It is the characteristic of every wise artist and architect, that he selects the most proper means to accomplish the end intended, and proportionates every part of a machine or edifice to all the other parts, so as to produce a harmony and unity of design. A philosophical instrument-maker, for example, in constructing an orrery does not make wheels of a hundred yards in diameter for carrying balls of less than an inch in diameter round a circle of only six feet in circumference; nor does a watchmaker employ two hundred wheels and pinions in the construction of a timepiece when less than a dozen may suffice; nor does an architect make the portico of an edifice five hundred times larger than the whole structure. Were any individual to act in this manner, he would at once be denounced as utterly destitute of wisdom, and viewed as a fool or a maniac. Now, we are to consider the Almighty, in all his arrangements throughout the universe, as acting on the same general principle which directs a wise and intelligent artist in all his plans and operations; for wisdom is an essential attribute of the Divinity, and all his works, when minutely inspected, must necessarily display this perfection to intelligent minds. To suppose otherwise, to imagine for a moment either that he has not proportionated one part of the universe to another, or that the greater part of it was created for no use at all, would be the height of profanity and impiety, and would rob the eternal Majesty of Heaven of one of the most distinguishing attributes of his nature. Bearing this principle in mind, we are necessarily led to the conclusion—a conclusion as certain as any mathematical demonstration—namely, that the benefit of the inhabitants of our globe was *not* the chief or ultimate design for which the stars were created, but that the Deity had a higher and more expansive design to accomplish in their formation. We do not pretend to fathom *all* the subordinate designs the Creator may have had in his view in the creation of the stars, or of any other object; but as he has endowed us with rational faculties for the investigation of his works, it is evident that he intended we should be able to discover *some* of the main and leading designs which he intended to accomplish in the formation of the great bodies of the universe.

We therefore maintain that one of the grand and leading designs of the creation of the stars was, that they should serve as *suns* to give light to other worlds and systems with which they are more immediately connected. This proposition I have all along taken for granted in the preceding pages, and shall now adduce a few arguments to elucidate and support it.

1. *They all shine by their own native light.* This is the peculiar characteristic of a sun in distinction from the planetary globes, which all shine with *reflected* light, derived from the luminous centre around which they revolve. The immense distance at which the nearest stars are placed from our globe is a clear proof that they shine, not with borrowed, but with inherent splendour; for reflected light from such a distance would be entirely dissipated ere it could reach our eyes. This likewise appears from actual observation, and from a comparison of the brilliancy of the fixed stars with that of the planets, in which there is found a striking difference. Mercury and Venus are the two planets which revolve in the immediate neighbourhood of the sun, and consequently derive from him a greater portion of light than any of the other planets;

yet it is found that the lustre of the star *Sirius*, and even that of *Capella*, is much more brilliant than that of either Mercury or Venus; and it is demonstrably certain that both these stars are situated far beyond the orbit of Uranus; and therefore, if they derived their light from the sun, they behoved to be incomparably more obscure than any of the planets. The lustre and brilliancy which the fixed stars exhibit when viewed with telescopes of large apertures and powers is exceedingly striking. Sir W. Herschel seldom looked at the larger stars through his forty feet telescope, because their blaze was injurious to his sight. At one time, after sweeping a portion of the heavens with that instrument, he tells us that "the appearance of Sirius announced itself at a great distance like the dawn of the morning, and came on by degrees, increasing in brightness, till this brilliant star at last entered the field of the telescope with all the splendour of the rising sun, and forced me to take my eye from the beautiful sight." These and other circumstances clearly show that the stars are endued with native splendour, and are not dependent on any other luminaries for the brilliancy they display, and consequently are fitted to act as suns for the illumination of opaque globes with which they are more immediately connected.

2. *They are placed at an immense distance* from our earth and from one another, and consequently it is impossible that they could derive their lustre from our sun; for the sun in his present situation could afford them no more light than a single star transmits to our globe; and to some of the more distant stars his rays would be altogether invisible. And if the sun cannot be supposed to enlighten any of those orbs, from the distance at which he is placed, there is no other body known to us whence their light may be derived, if they do not shine with their own native splendour.

3. *They are bodies of immense magnitude.* We have already shown, both from mathematical considerations and popular illustrations, that the stars are unquestionably at a very great distance from our globe, a distance which is almost incomprehensible. (Chap. IV.) Their bulk must therefore be very great. If they were no larger than the globe on which we live, they would be altogether invisible, even although they shine with their own native light. Few of them can be considered as much less than our sun, and the greater number of them are in all probability much larger; they are therefore fitted by their enormous size, and their consequent attractive power, to be the centres of systems of planetary worlds, and to diffuse around them to an immense distance a splendid illumination. But it would be absurd to suppose that such a number of vast luminous globes, placed at such immense distances from each other, and from the earth, could have been created solely for the benefit of the inhabitants of our world; for it would argue a want of wisdom in not proportioning means to ends; since a single star of the one-thousandth part of its present bulk, placed within a million of miles of the earth, would afford us far more light than all the stars put together.

4. Were we removed to the distance only of the nearest stars, our sun would appear no larger than one of those twinkling orbs, and from some of them he would disappear altogether; at most, he would appear only as *one* of the small stars which deck the firmament, and probably one only of the fifth or sixth magnitude; consequently all the planets of our system would entirely disappear. Even Jupiter and Saturn, though each of them is a thousand times larger than the earth, would be quite invisible, by reason of their comparative smallness and their shining only by *reflected* light. The system to which we belong cannot therefore be supposed to have any *immediate* connexion even with the nearest stars; and these stars must be considered as having appropriate purposes to fulfil in their own immediate sphere.

5. *The stars*, in point of number, size and splendour, *constitute almost the whole universe*, at least, so far as it has been unfolded to our view. The bodies which compose the planetary system contain a mass of solid matter about 2480 times larger than that of the earth, and the sun is about 500 times greater than the whole of them taken together. But this system, great as it appears in the eyes of mortals, is but as a diminutive ball, or even as a mere point, when compared with the myriads of stars which the firmament displays, and which the telescope has brought to view. These innumerable globes of light were created for *use*—to subserve important purposes in the plan of the Divine administration. They were not launched through the spaces of infinity at random, merely to display the energies of Omnipotence, and to light up the wilds of immensity with a useless splendour. Such a supposition would be derogatory to the attributes and character of the All-wise Creator, and would distort all the views we ought to entertain of a Being possessed of infinite perfection. Those immense bodies must therefore be conceived as intended chiefly to diffuse their light and splendour over worlds with which they are more immediately connected, and for the ultimate design of communicating happiness in various forms to the different orders of beings with which they may be replenished. What other sub-

ordinate ends they may accomplish in the grand scheme of the universe, besides the advantages we derive from them, is beyond our province to determine. It is not improbable, however, that every star or system, whether single, binary, or ternary, may have a subordinate end to serve to every other system, as forming parts of one whole under the government of Infinite Wisdom. As we derive advantages from these orbs, distant as they are, and as they diversify the ceiling of our earthly habitation with a splendid decoration, so they will likewise adorn the firmament of other systems, and display to the view of their inhabitants both the energies of Omnipotent Power and the manifold wisdom of God.

6. We *have some direct indications that the fixed stars are in reality suns.* It forms no argument against the idea of the stars being the centres of systems, that we have hitherto been unable to detect any of their revolving planets; for unless such planets be far beyond the magnitude of those belonging to our system, and unless their surfaces be fitted to reflect the rays of light with extraordinary brilliancy, we could not expect them to be visible at the remote distance at which we are placed, since the stars themselves appear only as shining points. But certain phenomena which have been observed, chiefly within the last century, give indication of the solar nature of the fixed stars. In the first place, there are phenomena which indicate that some of them at least, like our sun, have a rotation round their axes. In Chapter VII. we have given a brief view of the phenomena of *variable* stars. One of these, named *Algol*, is found *regularly* to pass through a change of brightness from the second to the fourth magnitude, and again to its original brightness in two days and about twenty-one hours. The star $\beta$ Lyræ passes through a periodic variation, from the third to the fifth magnitude, in six days and nine hours. A star in Hercules varies its lustre periodically, in the course of sixty days and six hours. A star in Sobieski's shield changes from the fifth to the seventh or eighth magnitude, and returns to its greatest brightness, in a period of sixty-two days. These and many other stars give pretty evident indications of a rotation round their axes. Their periodic changes are *exact* and *regular*; and, in order to account for the phenomena, we have only to suppose that one of their hemispheres is either covered with large dark spots, or is encompassed with a medium which prevents it from emitting so much light to our eyes as the other, and that each hemisphere is presented to our view in alternate succession. Our sun, indeed, would not exhibit any sensible variation of lustre at the distance of the stars, notwithstanding some large spots on his surface; but we have no reason to conclude that the stars, although they are all luminous bodies, are exactly alike in every part of their constitution, since variety appears to be a characteristic of all the arrangements in the universe. The darker hemisphere of the stars to which we allude may produce a change of illumination, which will form an agreeable vicissitude to the inhabitants of the worlds which roll around them, and which may produce an effect somewhat analogous to that which is produced by the alternate shining of a white and a yellow sun, as in the case of some of the double stars, (see pp. 64, 65.)

Again, there are stars whose periods of variable lustre are much longer than those now stated. Some of them pass through their periodic changes in 331 days, some in 494 days, and others not till after the lapse of eighteen years. Such changes, at least in some instances, may be accounted for by the intervention of opaque revolving bodies, or planets of a large size, passing directly between our eye and the stars, when revolving through that half of their orbits which lies next the earth. It is almost certain that either the one or the other of the circumstances now mentioned is the cause which produces the phenomena of variable stars, and in either case a strong presumption is afforded of the reality of other planetary systems. If *rotation* be the cause of the changes alluded to, the analogy between our sun and the stars is almost verified, for the most eminent philosophers have always considered that the rotation of an orb is necessarily connected both with motion in space, and with the existence of revolving planets. If such changes arise from the interposition of opaque globes, as is highly probable in some of the cases we have stated, then we have direct evidence that the stars are in reality the centres of systems, and that their planets are constructed on a scale of magnificence far surpassing that of our solar system, (see Ch. VII. pp. 53, 54.) It is highly probable that both the causes to which we have now adverted operate in producing the phenomena of variable stars. Those whose periodic variations are the shortest may be produced by rotation, and those in which years are requisite to accomplish all the changes, may arise from the intervention of very large opaque revolving bodies.

It has been surmised by some astronomers that certain very small stars which accompany larger ones probably shine by reflected light. Sir John Herschel, a few years ago, called the attention of astronomical observers to this point. The stars to which he has requested particular attention are such as the follow-

ing:—ι Ursæ Majoris, γ Hydræ, κ Geminorum, α 2 Cancri, α 2 Capricorni, and several others. *Iota* Ursæ is a star of the third or fourth magnitude, in the fore-foot of the Great Bear: right ascension, 8h 46′ 54″; north declination, 47° 51′ 20″. *Gamma* Hydræ is a star of the fourth magnitude, about thirty-five degrees south-east from Regulus, and about twenty-nine degrees west by south from Spica Virginis: right ascension 11h 15′ 57″; south declination, 16° 42′. *Kappa* Geminorum is a star of the fourth magnitude, situated about three degrees and a half south of Pollux: right ascension, 7h 33′ 38″; north declination, 24° 49′. The star α 2 Capricorni is of the third magnitude, about twenty-two degrees south by east of Altair, and about two degrees and a half north of β Capricorni, &c. It is to the very small and point-like stars which accompany these that the attention is to be directed; they are minute points of light which can only be perceived by telescopes of considerable power. Some of these are suspected as shining with reflected light; and if this point could be ascertained, it would form *a direct proof* of planets circulating around stars and enlightened by their beams. We have reason to hope, from the increase of astronomical observers, from the accuracy with which sidereal observations are now conducted, and from the improvements of which the telescope is still susceptible, that this interesting fact, will, ere long, be determined by ocular demonstration; and when such a discovery shall have been made, the telescope, which has already disclosed so many wonders, will then have performed one of its most sublime and mighty achievements.

In the mean time, we have no reason to entertain the least doubt that the stars are in reality *suns* and the distributors of light to other worlds any more than we ought to doubt of the motion of the earth, because we have never, from a fixed point in the firmament, beheld it wheeling its rapid course through the ethereal spaces around the sun. Since the stars cannot, with the least show of reason, be supposed to have been created chiefly for the use of our globe, it is as certain as moral demonstration can make it, that they were principally intended to fulfil a higher and a nobler purpose, and that this purpose has a respect to the accommodation and happiness of intelligent existence, either in the stars themselves or in worlds which revolve around them; for the Creator and Governor of the universe must be considered, in all his arrangements, as acting in perfect consistency with those perfections of his nature with which he is eternally and essentially invested. But to suppose the innumerable host of stars to be only so many vast insulated globes, hung up to irradiate the void spaces of infinitude, would be repugnant to all the conceptions which reason and revelation lead us to form of a Being of infinite perfection.

If, then, the fixed stars are the centres of light and influence to surrounding worlds, how immense must that empire be over which the moral government of the Almighty extends!—how expansive the range, and how diversified the order of planetary systems!—how numerous beyond calculation the worlds which incessantly roll throughout the immensity of space! What countless legions of intellectual beings, of every rank and capacity, must crowd the boundless dominions of the King eternal, immortal, and invisible! and how glorious and incomprehensible must He be whose word caused this vast fabric to start into existence, and who superintends every moment the immensity of beings with which it is replenished! In attempting to grasp such scenes the human mind is bewildered and overwhelmed, and can only exclaim, "GREAT AND MARVELLOUS ARE THY WORKS, LORD GOD ALMIGHTY."

"Seest thou these orbs that numerous roll above?
Those lamps that nightly greet thy visual powers
Are each a bright capacious sun like ours.
The telescopic tube will still descry
Myriads behind that 'scape the naked eye,
And further on a new discovery trace
Through the deep regions of encompassed space.
If each bright star so many suns are found
With planetary systems circled round,
What vast infinitude of worlds may grace,
What beings people the stupendous space?
Whatever race possess the ethereal plain,
What orbs they people, or what ranks maintain?
Though the deep secret heaven conceal below,
One truth of universal scope we know;
Our nobler part, the same ethereal mind,
Relates our earth to all their reasoning kind,
One Deity, one sole creating cause,
Our active cares and joint devotion draws."

## CHAPTER XV.

### *On unknown Celestial Bodies—on Meteoric Phenomena—and on Shooting Stars.*

WE are not to imagine that we have yet discovered the greater part of the bodies which exist in those spaces whose range lies within the reach of our telescopes. All the discoveries which have hitherto been made in the heavens have been owing to the *light* emitted

by very distant orbs having been concentrated on the eye by the magnifying and space-penetrating power of the telescope; but it is not improbable that there are numerous bodies within the circuit of the visible heavens which send forth no rays of light susceptible of being refracted or reflected to the eye by our finest instruments. Some of the largest bodies in the universe may either be opaque globes, or so slightly illuminated that no traces of their existence can ever be perceived from the region we now occupy. The greater part, if not the whole, of the orbs which have been described in the firmament, with the exception of the planets and comets of our system, are globes which shine with their own inherent lustre, without which their existence would have been to us for ever unknown. We are not warranted to call in question the existence of any class of bodies merely because our limited organs of perception and our situation in the universe prevent us from perceiving them. We have never yet beheld the planets which doubtless circulate around other suns, although there can be no question that such bodies really exist; and there may be opaque globes of a size incomparably larger than either planets or suns, which may serve as the centres of certain systems, or for some other important purposes to us unknown; for all that we have yet explored of the distant regions of creation is but the mere outskirts of that boundless empire which stretches out on every hand towards infinity. It is not unreasonable to believe that the number of magnificent bodies imperceptible to our organs of vision may far exceed all that we have hitherto discovered either by the naked eye or the telescope, even within the compass of that region which lies open to human inspection.

It has been remarked by La Place, that "a luminous star of the same density as the earth, and whose diameter should be two hundred and fifty times larger than that of the sun, would not, in consequence of its attraction, allow any of its rays to arrive at us." "A star which, without being of this magnitude, should yet considerably surpass the sun, would perceptibly weaken the velocity of its light, and thus augment the extent of its aberration." It is therefore *possible* that the largest *luminous* bodies in the universe, if their internal structure be composed of dense materials, would be invisible to us, in consequence of their great attractive power preventing their light from reaching the system to which we belong. In Chapter XII. I have given a brief view of the ideas entertained by Lambert respecting the arrangement of the universe into distinct systems of stars which have a more immediate connexion with one another in consequence of the law of mutual gravitation, and whose views have been partly confirmed by the discoveries of Herschel. This illustrious mathematician and astronomer endeavours to prove, by an induction of facts and reasonings, that, in order to the stability of those systems, it is necessary, on the principles of universal gravitation, that there be a large central body, around which all the individuals which compose the system revolve. There is no necessity that such a central body should possess original or underived light. The fixed stars do not stand in need of it; and as for itself, if it require illumination, it will receive it from the suns that are more immediately adjacent. As to the *magnitude* of such a centre, Lambert estimates that the central body of the system to which we belong must have a diameter at least equal to the whole circumference of the orbit of Saturn. "The magnitude of those bodies," he says, "ought not to alarm us, for, in the first place, we have nothing to do with their bulk, but with their density or quantity of matter by which the law of gravitation is regulated. We have no idea of the density of matter that is not porous; perhaps gold, the most dense of terrestrial substances, would be found a mere sponge compared with such a central body. Besides, nothing is great or small in immensity; and since on the wing of light we can traverse the vast regions of the heavens, matter and volumes ought no longer to excite our astonishment. Beginning with the satellites, even suns are but bodies of the first magnitude; the centres of the fixed stars, of the fourth; those of groups of systems, of the fifth, and so of the rest."

Lambert supposes that since such bodies must be of enormous bulk, and illuminated besides by one or more fixed stars, it might be possible to perceive the one which belongs to our own system, either in whole or in part, with the help of the telescope; that its apparent diameter may be very considerable; that, however weak its reflected light, it may not be enfeebled to such a degree as to be rendered imperceptible; that, being enlightened by one or more suns, it ought to present phases analogous to those of the moon; that such a central body ought to extend its influence even to the extremities of its system, and consequently ought to appear under a sensible diameter, or at least be visible by the telescope; and that as the attractive force of a body decreases as the square of the sine of its apparent semi-diameter, so this apparent semi-diameter cannot be invisible in any place to which its attractive force and its sphere of activity extend. Without sanctioning all the opinions which this ingenious mathematician has thrown out on this point, we may admit

that the subject is worthy of special attention, and might be kept in view when we are exploring the heavens with our best telescopes. What if some of the planetary nebulæ be bodies of a nature similar to those to which we have now alluded?

If opaque globes of a prodigious size exist throughout the regions of the firmament, as there is reason to believe, they would afford us a clue for unravelling certain phenomena which have hitherto remained in some degree inexplicable. Stars have appeared all at once, and, after having shone for a year or more with a brilliant light, have gradually disappeared. Certain stars are found to pass through regular variations of lustre, and for a certain period entirely disappear, but after a lapse of a certain number of months or days reappear, and resume their former brightness. On the supposition that opaque bodies exist nearly in the direction of such stars, some of these phenomena would admit of an easy explanation. Their appearing and disappearing might be nothing more than an occultation or an eclipse, caused by the interposition of the opaque globe between our eye and the star. This would, indeed, suppose *motion* to exist either in the opaque body, or in the star, or in the eye of the observer; and perhaps the annual motion of the earth, or the motion of the sun in absolute space, might contribute, in a certain degree, to produce the effect. Motion, of some kind or other, must necessarily be supposed, in order to account for the phenomena of variable stars, whatever hypothesis we may adopt for their explanation; but as nothing decisive can be stated on this subject, in the mean time I shall proceed to the consideration of some meteoric phenomena which are now supposed to have a connexion with certain moving bodies in the heavens.

### *Meteoric Phenomena and Shooting Stars.*

In my volume entitled "Celestial Scenery," when describing the small planets Vesta, Juno, Ceres, and Pallas, I have given a detail of certain facts respecting the fall of large masses of solid matter from the higher regions of the atmosphere, usually denominated *meteoric stones*, which, there is every reason to believe, descend from regions at a considerable distance, and even beyond the sphere of the moon. Such phenomena seem to indicate the probability that certain opaque bodies, of different dimensions, are revolving through space in certain regions within the limits of our system. "Nor is this," says Mrs. Somerville, "an unwarranted presumption; many such do come within the sphere of the earth's attraction, are ignited by the velocity with which they pass through the atmosphere, and are precipitated with great violence upon the earth. The fall of meteoric stones is much more frequent than is generally believed. Hardly a year passes without some instances occurring; and if it be considered that only a small part of the earth is inhabited, it may be presumed that numbers fall in the ocean, or on the uninhabited part of the land, unseen by man. They are sometimes of great magnitude; the volume of several has exceeded that of a body of seventy miles in diameter. One which passed within twenty-five miles of us was estimated to weigh about 600,000 tons, and to move with a velocity of about twenty miles in a second, a fragment of it alone reached the earth. The obliquity of the descent of meteorites, the peculiar substances they are composed of, and the explosion accompanying their fall, show that they are foreign to our system."

But, without resuming the consideration of this particular phenomenon, there is another which of late years has excited a considerable degree of attention, and which may proceed from a cause somewhat similar, to which I shall chiefly direct the attention of the reader—namely, the phenomenon of *shooting or falling stars*. This phenomenon, though most frequently observed in tropical regions, is common in all parts of the earth, and has been seen in almost every season of the year A shooting star seems to burst from a clear sky, and to dart across the heavens with a long train of light, which in a few seconds leaves no trace behind. Dr. Burney, of Gosport, for several years kept a record of such of these bodies as came under his own observation, and found that in the year 1819 there were 121, and in 1820 about 131; but a much greater number than these would doubtless be perceived could we detect all that make their appearance in the sky, the greater proportion, in all probability, being visible only during the hours usually allotted to sleep. Various opinions have been entertained respecting the cause of these appearances. Beccaria was of opinion they were occasioned by electricity, and brought forward the following facts as corroborative of his hypothesis:—About an hour after sunset, he and some friends that were with him observed a falling star directing its course directly towards them and apparently growing larger and larger, but just before it reached them it disappeared. On vanishing, their faces, hands, and clothes, with the earth and all the neighbouring objects, became suddenly illuminated with a diffused and lambent light. During their surprise at this appearance, a servant informed them that he had seen a light shine suddenly in the garden, and especially upon the streams that

he had been throwing to water it· when, sending up an electrical kite into the atmosphere, he likewise observed a quantity of electric matter about the kite, which assumed the appearance of a falling star. Whatever be the cause of shooting stars, it is pretty evident that they have their origin at a very considerable elevation above the earth. Brydone informs us that, from the top of Mount Etna, he noticed some of these meteors, "which still appeared to be as much elevated above us as when seen from the plain; so that in all probability those bodies move in regions much beyond the bounds which some philosophers have assigned to our atmosphere."

The most striking and remarkable form in which shooting stars have appeared is that of "meteoric showers," when thousands of those bodies have appeared to sweep along at once, and in continued succession for several hours, so that almost the whole visible canopy of the sky seemed to be in a blaze. As this phenomenon has recently excited considerable attention among philosophers, and as it is now generally considered as connected with some moving bodies in the heavens, I shall, in the first place, give a detail of some of the more remarkable circumstances with which it has been attended, as described by those who were eye-witnesses of the scene. One of the most remarkable displays of the phenomena to which we allude is that which was seen on the evening of the 12th and the morning of the 13th of November, 1833, in the United States of America. The following account of it is abridged from the *New York Commercial Advertiser* of November 13, 1833:

"The sky was remarkably clear on the night of this remarkable phenomenon. Some time before twelve o'clock, the meteors so frequently seen on summer evenings, called *shooting stars*, were observed to fall with unusual frequency and splendour. They continued from that hour to flash athwart the skies more and more, until they were eclipsed by the glories of the rising sun this morning. From four to six they were most numerous and refulgent. Within the scope that the eye could contain, more than twenty could be seen at a time shooting (save upward) in every direction. Not a cloud obscured the broad expanse, and millions of meteors sped their way across it on every point of the compass. Were it possible to enumerate them in the swiftness of their arrowy haste, we might venture to say that for the space of two hours, intervening between four and six, more than a thousand per minute might have been counted. Their coruscations were bright, gleamy, and incessant, and they fell thick as the flakes in the early snows of December. In one instance we distinctly heard the explosion of a meteor that shot across to the north-west, leaving a broad and luminous track; and witnessed another which left a path of light that was clearly discernible for more than ten minutes after the ball, if such it be, had exploded. Its length was gradually shortened, widening in the centre, and apparently consisted of separate and distinct globules of light, drawing around a common centre, glimmering less and less vividly until they finally faded in the distance. Compared with the splendour of this celestial exhibition, the most brilliant rockets and fireworks of art bore less relation than the twinkling of the most tiny star to the broad glare of the sun. The whole heavens seemed in motion, and never before has it fallen to our lot to observe a phenomenon so magnificent and sublime."

Various similar accounts of the same phenomena were given in the *Philadelphia*, *Hartford*, *Boston*, and other newspapers of the same date, of which the following are extracts:

"From a point in the heavens, about fifteen degrees south-easterly from our zenith, the meteors darted to the horizon in every point of the compass. Their paths were described in curve lines similar to those of the circles of longitude on an artificial globe. They were generally short in their course, resembling much an interrupted line, thus —— —— ———. They ceased to appear when within ten degrees of the horizon. I did not see a single meteor pass the meteoric pole I have described, nor one pass in a horizontal direction. Several of them afforded as much light as faint lightning. One in the north-east was heard to explode with a sound like that of the rush of the distant sky-rocket. Millions of these meteors must have been darted in this shower. The singularity of this meteoric shower consisted in the countless number of the celestial rockets, and more especially in their constant uniform divergence from near the zenith."

The following was an account sent by Professor Thomson, of Nashville, to Professor Olmsted, of New Haven, of the meteors which appeared November 13, 1833, as seen in the State of Mississippi:—"About an hour before daylight I was called to see the falling meteors; it was the most sublime and brilliant sight I had ever witnessed. The largest of the falling bodies appeared about the size of Jupiter or Venus when brightest. The sky presented the appearance of a shower of stars, which many thought were real stars and omens of dreadful events. I noticed the appearance of a *radiating point*, which I conceived to be the vanishing point of straight lines as seen in perspective. *This point appeared to be stationary*. The meteors fell

to the earth at an angle of about seventy-five degrees with the horizon, moving from the east towards the west." The following is from a writer in the *Boston Christian Register*:—"My first attention was to determine the centre or point from which the meteors started, which, from the place where I stood, (lat. 42° 46′ N.,) appeared in the Lion's heart, near Regulus. There is one thing that I have not seen noticed by any that have written, and which could not have been noticed by me had I not kept my eye on the centre or point from whence the meteors all shot forth for a considerable time, and that was an appearance of a star less at first than the stars of the constellation by which it was surrounded, but it would increase until it was much larger than the stars, then totally disappear from ten to fifteen minutes, and then appear again; but the meteors shot forth in greater numbers in the interval between the appearances above mentioned."*

It is worthy of particular notice, that the point from which the meteors seemed to emanate was observed, by those who fixed its position among the stars, to be in the constellation Leo; and, according to their concurrent testimony, this *radiant point* was stationary among the stars during the whole period of observation—that is, it did not move along with the earth in its diurnal revolution *eastward*, but accompanied the stars in their apparent progress *westward*, which proves the elevation of the meteors to be far beyond our atmosphere. The following cut represents the appearance of these meteors for

Fig. 76.

several hours, as seen at Boston, New York, Philadelphia, and other places in the eastern parts of the United States. It is copied from one of the American periodicals published about the time when those phenomena appeared.

Meteoric phenomena nearly resembling what has been now described, have occurred at several former periods. One remarkable instance of what was called "showers of fire" occurred over eighty years ago in South America. At Quito, so many falling stars were seen above the volcano of Gayambo, that the inhabitants were led to imagine the mountain to be in flames. The people assembled in the plain of Exico, and a procession was about to set out in consequence from the convent of St. Francis, when they discovered the phenomenon to be occasioned by meteors which ran along the skies in all directions.

A more extensive and remarkable phenomenon of this kind occurred in the night of the 12th of November, 1779. Of this appearance, as it was seen at Cumana, an accurate account has been given by M. Humboldt and M. Boupland. It occurred towards the morning, when thousands of meteors, bolides, fire-balls, or falling stars, as they were variously denominated, succeeded each other during four hours. Their direction was from north to south. They rose in the horizon at east-north-east, followed the direction of the meridian, and fell towards the south. There was little wind, and this from the east. No trace of clouds was seen. There was not a space in the firmament equal in extent to three diameters of the moon which was not filled with burning stars. They were of different sizes; they left luminous traces of from five to ten degrees in length. The appearance of these traces continued seven or eight seconds. Many of the stars had a distinct nucleus as large as the apparent disk of Jupiter. The largest were from 1° to 1° 13′ in diameter. Their light was white, and they seemed to burst as by explosion. They were seen by all the inhabitants of Cumana, the oldest of whom asserted that the great earthquakes of 1766 were preceded by similar phenomena.

It is a circumstance worthy of particular notice, that these meteoric showers have taken place chiefly on the 12th and 13th of November, and hence they are now distinguished by the name of the *November Meteors*. Captain Hammond gives the following account of shooting stars seen at Mocha, on the Red Sea, November 13th, 1832, the day and month on which they have most generally been seen:—"From one o'clock, A. M., till after daylight, there was a very unusual phenomenon in the heavens. It appeared like meteors bursting in every direction. The sky at the time was clear, the stars and moon bright, with streaks of light and thin white clouds interspersed in the sky. On landing in the morning, I inquired of the Arabs if they had noticed the above. They said they

* This astonishing exhibition covered a very considerable part of the earth's surface. It has been traced from the longitude of 61° in the Atlantic Ocean to 100° in Central Mexico, and from the North American lakes to the West Indies.

had been observing it most of the night. I asked them if ever the like had appeared before? The oldest of them replied that it had not."

On the morning of the 12th of November, 1799, a remarkable phenomena of this kind was seen by Mr. Ellicot, near Cape Florida, which he thus describes:—"The phenomenon was grand and awful; the whole heavens appeared as if illuminated with sky-rockets, which disappeared only with the light of the sun after daybreak. The meteors, which at any one instant of time appeared as numerous as the stars, flew in all possible directions, except *from* the earth, *towards* which they all inclined more or less, and some of them descended perpendicularly over the vessel we were in, so that we were in constant dread of their falling on us." The same appearances were observed *on the same night* at Santa Fe, Cumana, Quito, and Peru, in South America, as far north as Labrador and Greenland, and as far east as Weimar in Germany; thus having been visible over an extent on the globe of 64° in latitude, and 94° of longitude. Meteoric showers were also seen on the morning of the 13th of November, 1831, in the Ohio country, and along the coast of Spain.

Flights of shooting stars, more or less numerous, have been seen in different places, both in Europe and America, at the same period—namely, the 13th of November, in the years 1834, 1835, 1836, and 1837, so that they are now considered as a regular periodical phenomenon. In a letter I received, in 1837, from Elijah H. Burrett, Esq., A. M., a scientific gentleman in the state of Connecticut, and a correspondent of Professor Olmsted, he has the following notice on the subject:—"With respect to the shooting stars, I believe Professor Olmsted is now very strong in the belief that they are exactly *periodical* and *annual*. The recurrence of this singular phenomena on the morning of the 13th of November, 1836, and very nearly at the same hour,—the radiation of the meteors from the same point of the heavens, differing only one half a degree, (as did those of 1834,) namely 145° right ascension in the face of Leo, and all the attending phenomena being the same, though upon a scale less magnificent,—settle the question as to its being a regular and annual phenomenon. According to his notion, the zodiacal light is an attribute of the same cause, or an emanation from the same radiant. Accordingly, my friend Dr. Olmsted was fortunate enough to see just so much of the zodiacal light last May as to enable him to identify it with the phenomena of November, 1834, except that it was in the other node."

One of the most remarkable circumstances attending this display, in 1833, was, that the meteors all seemed to emanate from one and the same point, a little south-east of the zenith. Following the arch of the sky, they ran along with immense velocity, describing in some instances an arc of 30° or 40° in a few seconds. On an attentive inspection, it was seen that the meteors exhibited *three* distinct varieties; the *first* consisting of *phosphoric lines*, apparently described by a point; the *second*, of large *fire-balls* that at intervals darted along the sky, leaving luminous trains which occasionally remained in view for a number of minutes, and in some cases for half an hour or more; the *third* of undefined *luminous bodies*, which remained nearly stationary in the heavens for a considerable time. Those of the first variety were the most numerous, and resembled a shower of fiery snow driven with inconceivable velocity. The second kind appeared more like falling stars,—a spectacle which was contemplated by certain beholders with great amazement and terror. They were sometimes of enormous size. One of them seen in North Carolina appeared larger than the full moon rising, and its light rendered even small objects visible. The same ball, or a similar one, seen at New Haven, passed off in a north-west direction and exploded a little northward of the star Capella, leaving a train of peculiar beauty. The line of direction was at first nearly straight, but it soon began to contract in length, to dilate in breadth, and to assume the figure of a serpent scrolling itself up until it appeared like a luminous cloud of vapour floating gracefully in the air, where it remained in full view for several minutes. Of the third variety, the following are examples:—At Poland, State of Ohio, a luminous body was distinctly visible in the north-east for more than an hour. It was very brilliant, in the form of a *pruning hook*, and apparently twenty feet long and eighteen inches broad. It gradually settled towards the horizon until it disappeared. At Niagara Falls, a large luminous body, shaped like a *square table*, was seen near the zenith, remaining for some time almost stationary, emitting large streams of light.

The recurrence of this wonderful phenomenon at the same season of the year soon attracted the attention of the philosophers of Europe, and they resolved to watch more particularly the aspect of the nocturnal heavens in the month of November. The celebrated M. Arago made arrangements to procure simultaneous observations from the different parts of France, for the night between the 12th and 13th of November, 1836. The following is the substance of the report

which was published of these observations. The places at which observations were made, and the number of meteors counted, were as under:

| | |
|---|---|
| Paris, at the Observatory . . . . | 170 |
| Dieppe, 100 miles north-west of Paris . | 86 |
| Arras, 100 miles north of Paris . . . | 27 |
| Strasburgh, 250 miles east of Paris . . | 85 |
| Von Altemare, 260 miles south-east of Paris | 75 |
| Angou, 180 miles south-west of Paris . | 49 |
| Rochefort, 260 miles south-south-west of Paris . . . . . . . . . . | 23 |
| Havre, 120 miles west of Paris . . . | 300 |

Besides these positive observations, information was received of similar phenomena having been observed at other places. In the neighbourhood of Tours, for example, the peasants declared they had seen a rain of fire during the night; and in the valley of the Rhone, near Culloy, three asteroids succeeded each other with such rapidity that the people, seeing them through a fog, supposed them to be flashes of lightning, or a repetition of the brilliant aurora of the 18th of October. As in the great meteoric shower of 1833, so at this time the greater part of the falling stars which were particularly observed seemed to issue from a point in the constellation of Leo. Of those noticed at Bercy, fifty-seven traversed lines which if continued would have ended in that constellation; and of eighty-five observed at Strasburg, fifty-seven had similar courses. M. Arago purposes an inquiry whether, from their number, this shower of falling stars may or may not be considered unusual; and he gives the following comparisons: At Paris, on the preceding night, none were seen during an hour; from three to five were seen in the same space of time on the night after the shower, and from two to three on the second night. On the preceding night, at Bercy, not one was seen in two hours. At Von Altemare, on the 6th of November, none were seen during two hours' watching; on the 7th, there were four in four hours; on the 8th, none in three hours; on the 9th, one in six hours; and on the 14th, two in six hours.

I have been somewhat particular in stating the more remarkable circumstances connected with this phenomenon, as there is every reason to believe that it is produced by an unknown celestial body at a considerable distance from the earth; and I shall now proceed to give a brief view of the opinions which certain philosophers entertain, and the deductions they have been led to make in reference to this subject.

In the "American Journal of Science" for April, 1834, Dr. Olmsted, professor of mathematics and natural philosophy in Yale College, New Haven, has entered into an elaborate investigation of this subject in a communication which occupies about forty-two pages. The whole of this paper is well worthy of the attentive perusal of the philosophic inquirer, but the limits to which I am necessarily confined in this chapter will permit me to state only the *general results* of the professor's investigations; all of which appear to be deduced from the phenomena with great acuteness and ingenuity of reasoning. These results are:

1. That the meteors of November 13 *had their origin beyond the limits of our atmosphere.* For the source of the meteors did not partake of the earth's motion, which was demonstrable from a variety of circumstances, some of which have been alluded to above.

2. That *the height of the place whence the meteors emanated*, above the surface of the earth, *was about* 2238 *miles.* This was ascertained from a comparison of different observation made in different places, and from trigonometrical calculations founded upon them.

3. *The meteors fell towards the earth, being attracted to it by the force of gravity.* It seemed unnecessary to assign any other cause, since gravity is adequate to produce the effect.

4. *They fell towards the earth in straight lines, and in directions which, within considerable distances, were nearly parallel with each other.* The courses are inferred to have been straight lines, because no others could have appeared to spectators in different situations to have described arcs of great circles.

5. *They entered the earth's atmosphere with a velocity equal to about four miles per second*, or more than ten times greater than the maximum velocity of a cannon ball, and about nineteen times that of sound. This was inferred from the laws of falling bodies.

6. *The meteors consisted of combustible matter, and took fire and were consumed in traversing the atmosphere.* They were seen glowing with intense light and heat, increasing in size and splendour as they approached the earth. They were seen extinguished in a manner in all respects resembling a combustible body like a sky-rocket; and in the case of the larger, a cloud of luminous vapour was seen as the product of combustion. That they took fire *in the atmosphere* is inferred from the fact that they were not luminous in their original situation in space, otherwise the body from which they emanated would have been visible.

7. *Some of the larger meteors must have been bodies of great size.* Some of them appeared larger than the full moon rising. Such

a body seen at 110 miles distance behoved to have been one mile in diameter; at fifty-five miles, one-half mile; at 22 miles, one-fifth of a mile; at 5½ miles, one-twentieth of a mile, or 264 feet.

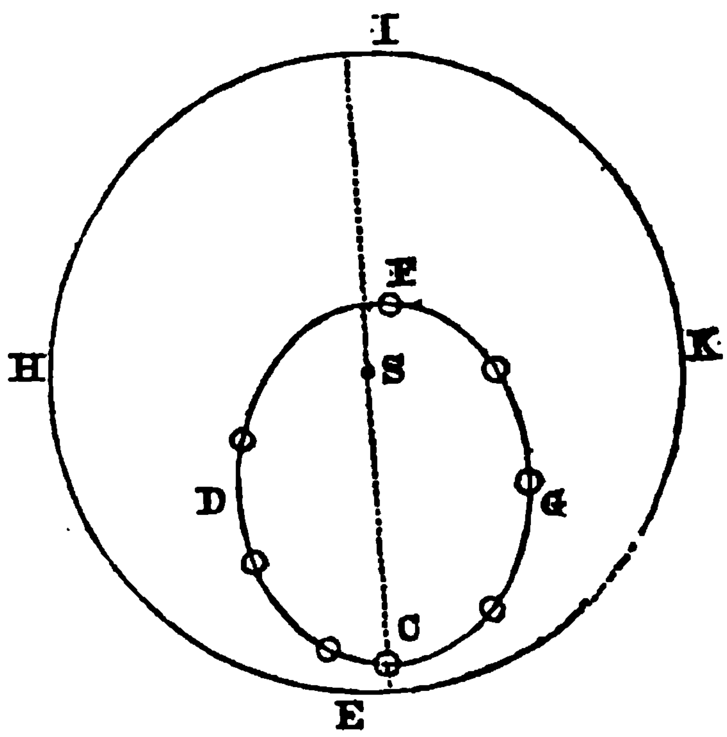
8. *The meteors were constituted of light and transparent materials.* They were of light materials, otherwise their momentum would have been sufficient to enable them to make their way through the atmosphere to the surface of the earth. They were transparent bodies, otherwise we cannot conceive how they could have existed together in their original state without being visible by reflected light.

9. The next, and one of the principal subjects of inquiry was, *What relations did the body which afforded the meteoric shower sustain to the earth?* Was it of the nature of a satellite that revolves round the earth as its centre of motion? Was it a collection of nebulous matter which the earth encountered in its annual motion? or was it a comet which chanced at this time to be pursuing its path along with the earth around their common centre of motion? It could not have been a satellite, because it remained so long stationary with respect to the earth; nor was it a *nebula*, either stationary or wandering lawless through space. Such a collection of matter could not remain *stationary* within the solar system; and had it been in motion in any other direction than that in which the earth was moving, it would soon have been separated from the earth, since during the eight hours while the meteoric shower lasted, the earth moved in its orbit through the space of 540,000 miles. The conclusion to which Professor Olmsted arrives, after a due consideration of all the circumstances, is the following:

*That the meteors of November 13th consisted of portions of the extreme parts of a nebulous body, which revolves around the sun in an orbit interior to that of the earth, but little inclined to the plane of the ecliptic, having its aphelion near to the earth's path, and having a periodic time of 182 days nearly.*

This conclusion, the professor thinks, will account for the following, among other circumstances:—Why the phenomenon remained so long stationary with respect to the earth; why it was seen in that particular part of the heavens; and why it returns at stated periods, having appeared at Mocha, in Arabia, just one year preceding, and in a manner very similar to the present, as described by Humboldt and by Ellicot thirty-four years before. It will likewise account for an auroral light, resembling daybreak, which was seen in the east several hours before the dawn of day, and it is also supposed it may account for the different appearances of the *zodiacal light*. The professor is of opinion that the body alluded to is somewhat analogous to that of a comet. Fig. 77 represents the supposed orbit of this body in relation to that of the earth. *E H I K* represents the orbit of the earth; *S*, the position of the sun; and *C D F G*, the supposed orbit of the body which was the source of the meteoric phenomena. At the time these phenomena were seen, the body is supposed to have been at *C* when the earth was at *E*.

Fig. 77.




Arago appears to entertain an opinion on this subject not very different from that of Dr. Olmsted. He supposes that there may be myriads of bodies, composed probably of *nebulous* matter similar to the tails of comets, circulating round the sun in a zone or ring that crosses the earth's orbit at that part where it is about the 12th November, and that some of them, drawn from their course by the earth's attraction, fall towards it, and taking fire when they enter the atmosphere, in consequence of their prodigiously rapid motion, present the luminous phenomena of falling stars. The body or bodies from which these meteors proceed, he considers as unquestionably in rapid motion, performing a revolution round the sun in some plane different from that of the earth's orbit; and that the apparent course of the meteors will be compounded of this proper motion and of the earth's motion in its orbit at the time. It follows, that the point from which they seem to come will be that towards which the earth is moving at the time, namely, the constellation *Leo*; for the line or tangent of the earth's annual motion at the 13th and 14th November points exactly to that constellation.*

* A gentleman in South Carolina thus describes the effect of the phenomenon of 1833 upon his ne-

Thus it appears that celestial bodies are revolving around us of which we formerly had no knowledge or conception. A new planetary system, within the limits of the old, is beginning to be revealed to us, the number of the bodies belonging to which may be much greater than we are yet aware of, and their particular properties and motions may at no distant period be detected and explained. This is one proof, among others, that bodies of a considerable size may exist in the heavens, and be prosecuting their courses in various directions, though they have never been detected by our telescopes. The subject is peculiarly interesting to philosophers and astronomers. The facts which have already been observed afford a *sensible proof* of the attractive power of the earth over bodies at a distance in the heavens; and it is to be hoped that the future observations and investigations of scientific men, in relation to such phenomena, will throw some further light on the nature and properties of bodies which have hitherto been involved in darkness and mystery. What the destination of such bodies may be, or the ends they serve in the economy of nature, we are as yet entirely ignorant of. It appears pretty evident that they are bodies of no great density, otherwise their effect on the earth might have been more terrific and disastrous. Had their quantity of matter been considerable, when accompanied with so prodigious a velocity as they evidently had, their momentum would have been such as to have dashed them with violence upon the earth, where the most appalling effects might have been produced, in the demolition of human habitations, and the destruction of thousands of their inhabitants. But it does not appear that any of them made their way through the atmosphere *to the surface of the earth*, which was doubtless owing to the comparatively light materials of which they were composed. This circumstance, along with many others, evidently shows that we may be surrounded with numerous bodies and substances impalpable to the organs of vision, any one of which might be sufficient to deprive us of our comforts, and even prove destructive to our existence, were it not under the direction and control of Infinite Wisdom and Benevolence.

## CHAPTER XVI.

### *Arguments Illustrative of the Doctrine of a Plurality of Worlds.*

Having in the preceding pages exhibited a condensed view of the principal facts in relation to the Sidereal Heavens, I shall now inquire into some of the designs which the Almighty Creator appears to have had in view in replenishing his universe with such an immense number and variety of magnificent orbs. In Chapter IX. of "Celestial Scenery," I entered on a consideration of this subject, and illustrated at some length a few leading arguments, which tend to prove that *matter* was created chiefly in subserviency to *mind*, and that the main object of the creation of the planets, as proved from all the decorations and special arrangements connected with them, was to afford habitations for numerous orders of sensitive and intellectual beings. Without resuming the consideration of any of the arguments there stated, I shall in this chapter offer a few additional arguments corroborative of the same position, which, taken in connexion with the former, will, I trust, amount to a moral demonstration that all the great globes in the universe are in some respect or another connected with intelligent existence.

I. The first class of arguments I shall illustrate is the following:—That *the doctrine of a plurality of worlds is more worthy of the perfections of the Infinite Creator, and gives us a more glorious and magnificent idea of his character and operations than to suppose his benevolent regards confined to the globe on which we dwell.*

1. The doctrine of a plurality of worlds is more accordant with the idea of the *infinity* of the Divine Mind than any other position. It is admitted by all rational theists and theologians that the Divine nature fills the immensity of space, and we consequently adore the Creator as an infinite and incomprehensi-

groes: "I was suddenly awakened by the most distressing cries that ever fell on my ears. Shrieks of horror and cries of mercy I could hear from most of the negroes on three plantations, amounting in all to about six or eight hundred. While earnestly listening for the cause, I heard a faint voice near the door calling my name. I arose, and taking my sword, stood at the door. At this moment I heard the same voice still beseeching me to rise, and saying, 'Oh, my God! the world is on fire!' I then opened the door, and it is difficult to say which excited me most—the awfulness of the scene, or the distressed cries of the negroes. Upwards of one hundred lay prostrate on the ground; some speechless, and some uttering the bitterest cries, but most with their hands raised, imploring God to save the world and them. The scene was truly awful; for never did rain fall much thicker than the meteors fell towards the earth, east, west, north, and south, it was the same!"

ble being. But we can have no ideas approximating to what infinity really is, unless by the prospects opened to us of the indefinite extension of material existence. Beyond the limits we may assign to the material world, our ideas, if we have any ideas at all, run into confusion, and approximate to inanity. It does not comport with the idea of a Being of infinite perfection that his works should be confined to one point of infinite space, or that one comparatively small race of intelligent beings should be the sole object of the moral government of Him whose presence fills the regions of immensity. It is more corresponding to the conceptions we ought to form of such a Being that the immensity of his works should correspond, in some degree, to the immensity of his nature; and, so far as our knowledge and observation extend, this is in reality the case. Beyond the range of natural vision, the telescope enables us to descry numerous objects of amazing magnitude; and, in proportion to the excellence of the instrument and the powers applied, objects still more remote in the spaces of immensity are unfolded to our view, leaving us no room to doubt that countless globes and masses of matter lie concealed in the still remoter regions of infinity, far beyond the utmost stretch of mortal vision. But huge masses of matter, however numerous and widely extended, if devoid of intelligent beings, could never comport with the idea of happiness being coextensive with the range of the Creator's dominions. Such an idea would completely obscure the lustre of all his other attributes, and prevent them from being known and appreciated wherever his Omnipotence is displayed. To consider creation, therefore, in all its departments, as extending throughout regions of space illimitable to mortal view, and filled with intelligent existence, is nothing more than what comports with the idea of HIM who inhabiteth immensity, and whose perfections are boundless and past finding out.

2. The idea of the indefinite extension of the universe and a plurality of worlds is most accordant with the *eternity* of the Divine Mind. When we go back in imagination to ages and centuries of duration more numerous than the drops of ocean or the sands on the sea-shore, we find the Deity existing in all the plenitude of his incommunicable attributes; for "He inhabiteth eternity," as well as immensity. There is nothing repugnant either to reason or revelation to suppose that, innumerable ages before our globe was arranged into its present state, many regions of infinite space were replenished with material existence; for the Scriptures nowhere assert that the *materials* out of which our globe was arranged were brought from nothing into existence *at the period* when Moses commences his narrative of the processes which preceded the formation of man. Nor have we any reason to believe that the operations of Creating Power have ceased since the structure of our world was completed, but have some evidences of the contrary; for example, in the case of *new stars*, which have made their appearance at different periods since the time of the Mosaic creation, and even within the limits of the last century. It does not appear corresponding to the idea of an *Eternal* Being, whose existence can never terminate, and whose perfections are the same at all periods of duration, that every thing should stand still in the universe, and that nothing new should arise into existence during the lapse of infinite duration, which would in effect be the case if the work of creation were absolutely finished, or if man were the principal intelligence connected with the material system.

Whether the happiness of the Divinity may be increased by the contemplation of his purposes and plans being brought into effect, we cannot positively declare; though it does not appear contrary to reason or the dictates of Scripture to suppose that even the felicity of the Deity may, in a certain limited and modified sense, be susceptible of augmentation.* But whatever opinion may be formed on this point, from the constitution of *finite* minds, and the principles and desires implanted in them, it appears necessary to *their* progressive enjoyment that new scenes and manifestations of Divine perfection should be continually opening to their view; and if the universe be indefinitely extended, as it appears to be, and if new worlds are continually springing up under the creating hand of the Omnipotent, then we behold a prospect of progressive knowledge and enjoyment suited to the desires and aspirations of intelligent minds, which can never terminate throughout all the future periods of eternity. It is indeed *absurd* to suppose that a Being without be-

* It is declared in Psalm cxlvii. 11: "The Lord taketh pleasure in them that fear him, in those that hope in his mercy;" and in relation to Messiah it is said, "Jehovah is well pleased for his righteousness' sake." In reference to the material works of creation it is said, Psalm civ. 31, "The glory of the Lord shall endure for ever; *the Lord shall* REJOICE *in all his works*." The expression, "The glory of the Lord," denotes the display of the Divine perfections made in the works of creation, as is evident from the subject of the psalm in which it occurs, which celebrates the power, wisdom, and providence of God, in relation to the objects of the visible world. In reference to these objects it is said, "The Lord shall *rejoice*" in them, which seems to imply, speaking after the manner of men, a degree of pleasure or satisfaction in beholding his wise and benevolent plans, and his eternal purposes, brought into effect and fulfilling the ends intended.

ginning and without end should have his attention solely or chiefly directed to one point of his universe, and to one class of intelligences, "to whom," in point of number and of rank, "they are counted as nothing, and less than nothing, and vanity."

In respect to a Being, then, who fills the infinity of space with his presence, and who is possessed of eternal duration, it is nothing more than what is consistent with these attributes, and what we should naturally expect, that his empire should stretch over the regions of immensity, and that it should be filled with innumerable intelligences, capable of appreciating his power and goodness, and of paying a tribute of gratitude and adoration. The two attributes to which we have adverted could never be thoroughly displayed to finite minds, unless creation were extended through the illimitable tracks of space, and new creations gradually unfolding themselves to view. Were creation as limited as many suppose, were it confined chiefly to the world in which we dwell, and the beings connected with it, we might in the course of a few ages be said in some measure to comprehend the Creator, having explored all the displays he has made of his power, wisdom, and goodness; for we know nothing more of the Deity than the *manifestations* he has made of himself in his works and his moral dispensations. Every thing in relation to man and his habitation might be known after the investigations of a very limited number of ages, and nothing further would remain to stimulate the exercise of the rational faculties throughout all the succeeding periods of infinite duration. But we may rest assured that the Divine Being is absolutely incomprehensible, and that no created intelligence will ever be able to sound the depth of his perfections, or to trace the full extent of his operations.

3. It is more accordant with the *wisdom* of the Deity that the universe should be inhabited by intelligent minds, than that it should remain in a state of perpetual desolation and solitude.

Could it be proved that the planets of the solar system, and all the other magnificent globes which are dispersed throughout creation, are only rude masses of matter, without life and intelligence, it would confound all our ideas of the intelligence of the Divine mind. Wisdom is universally acknowledged to be one of the eternal and essential attributes of the Divinity. But how could the glory of this attribute be traced from the contemplation of a mass of mere inanimate matter, however vast and splendid in its general aspect, when no end or design of its creation is perceived? Where should we be enabled to perceive the nice adaptation of means to ends? the harmonious operation of principles and causes producing grand and beneficent effects? the accomplishment of glorious and useful designs by admirable arrangements? We could only behold a vast and stupendous assemblage of means *without an end;* or, at least, without an end corresponding to their magnitude and grandeur. We should behold merely a display of boundless and uncontrollable *power* acting at random, and producing no effect which could excite the love and admiration of holy intelligences. For what could they behold to excite such emotions, although they were permitted to make the tour of the universe? Scenes of emptiness and desolation, of silence and solitude, where no sound is heard, where no animated being enlivens the boundless prospect, where no interchange of sentiment or affection can take place, and where no praises from adoring worshippers ever ascend to the Ruler of the skies. A rational being traversing scenes of this description would feel as little enjoyment as a bewildered traveller, amidst storms and tempests, wandering over a vast howling wilderness, where human feet had never trod, and where the sweet accents of the human voice are never heard to cheer the surrounding solitude.

But when we view the magnificent globes which are scattered throughout immensity as replenished with numerous orders of intelligent beings, we behold an *end* worthy of the grandeur of the means which have been employed, worthy of the omnipotent power which has been exerted, and corresponding to the perfections of him who is "the only wise God," who is "wonderful in counsel, and excellent in working." We behold a display of Divine wisdom and munificence which is calculated to arrest the attention and draw forth the admiration of all rational beings, and to excite the most ardent desires of beholding the distant scenes of the universe more completely unfolded—a display calculated to gratify intelligences of the highest order, and of the most capacious powers, to excite them to the most sublime investigations, and to inspire them with emotions of love, reverence, and adoration of Him who created all worlds, and for whose pleasure they are and were created.

4. The idea of the universe being replenished with sensitive and intellectual existence is accordant with every rational view we can take of the *goodness* or *benevolence* of the Deity.

The goodness of God is that attribute of his nature by which he delights to communicate happiness to all the ranks of his sentient and intelligent offspring. Like every other attribute of the Divine mind, it is strictly

boundless or infinite, coextensive with the eternal greatness of that mind, and commensurate with infinite knowledge, wisdom, and omnipotence. The benevolence of the Deity may be said to constitute his whole moral character, and to reflect a radiance on all his other perfections. To his *love* of happiness, as it now exists among every order of his creatures, and to his *desire* of producing it in all his future arrangements, no possible limits can be affixed. Hence, in the sacred records, the Divine Being is summarily described by this perfection alone, "*God is love.*" It is not merely asserted that God is benevolent, but that he is *benevolence* itself. Benevolence is the essence of his being and character—a summary of every thing that can render him amiable and adorable in the eyes of all his intelligent creatures. This benevolence is permanent and immutable, and must be *for ever active* in distributing blessings wherever percipient beings exist. As it consists in the love of happiness, and the desire of communicating it wherever there is scope for its exercise; as it is the boundless energy of the infinite Mind in unceasingly doing good, it must be displayed, in a greater or less degree, wherever matter exists, and wherever wisdom and omnipotence have been exerted throughout the universe. We know that it is incessantly displayed throughout all the departments of our terrestrial system, in the ample provision made for the wants of every species of animated existence, in "giving" the various tribes of men "rain from heaven and fruitful seasons, and filling their hearts with food and gladness;" and, in a wonderful diversity of modes, distributing enjoyment among percipient beings. It is celebrated in the highest strains by the inspired writers as one of the most glorious and distinguishing characteristics of Jehovah. "The Lord is good to all; his tender mercies are *over all* his works." "He is merciful, and gracious, and *abundant* in goodness." "His bounty is great above the heavens," and "he exercises loving kindness throughout the earth." "O give thanks to the Lord, for he is good, for his mercy endureth for ever."

But however great and inexhaustible the source of happiness in the Divine mind, the *exercise* of goodness *necessarily supposes the existence of sensitive or rational beings*, towards whom benevolence may be displayed. Where no such beings are to be found, this attribute cannot be exercised or traced in its operation. Mountains and plains, rocks of marble and diamonds, or valleys adorned with all manner of precious stones, however rich and splendid, cannot feel the effects of Divine beneficence. If, therefore, the numerous globes throughout the universe were destitute of inhabitants, there would be no extensive display of this essential perfection of the Divine nature; and to those few intelligences who might be permitted to view the desolate wastes of the universe, or to receive information respecting them, it would appear as if the Divine goodness had either been exhausted or had ceased its operations, and been withdrawn from the scene of creation, as if "the Lord had forgotten to be gracious, and in anger shut up his tender mercies." We have reason, however, to believe, both from scripture and from reason, that it is the great end of all the operations of Deity that a theatre may be prepared, on which the emanations of his goodness may be communicated to innumerable orders of beings throughout his vast creation. There is no other conceivable end for which the fabric of universal nature was reared than that it should serve as a scene of enjoyment to innumerable beings susceptible of feeling the effects of the Creator's bounty, and that therein they might behold a magnificent display of the grandeur of his eternal attributes; but if by far the greater part of creation were uninhabited, such an end would be frustrated. However expansive the scene of the universe may be—however numerous and magnificent the worlds and systems which exist within its boundless range, the glories of Omnipotence would remain for ever veiled and unknown, except to a small race of beings who occupy only a point in the immensity of space, and who cannot possibly be acquainted with the ten-thousandth part of the scenes which lie in the remoter spaces of creation.

If, therefore, we would not rob the Divinity of the most distinguishing attribute of his nature, we must admit that wherever creation extends, his goodness and beneficence are displayed, and, consequently, that intelligent beings of various orders must exist throughout all its amplitudes. Wherever power and wisdom are displayed, it ought to be considered as a necessary consequence that there also goodness is exercised, as the one is subsidiary to the other, and stands related as means to an end, or as cause to effect, It would be a most glaring piece of inconsistency to suppose that the Divine benevolence is confined to one or two worlds or orders of beings, when millions of expansive systems diversify the fields of immensity; more especially when we consider that the goodness of the Deity is of so *communicative* a nature that all the interval between a polypus and a man is filled with thousands of species of animated beings, of every conceivable form, and structure, and capacity, in order that happiness of every degree may be diffused among every possible order of sentient existence. Every element

of nature, every department of our terrestrial system, forms an appropriate abode for living beings. The air, the waters, and the earth teem with animated existence of every size and form, and in such vast multitudes as to exceed all human calculation; and if the displays of Divine goodness be thus exuberant in our sublunary world, it would be absurd in the highest degree to suppose for a moment that the millions of vast globes, which roll in the distant regions of creation are devoid of inhabitants, since the communication of happiness appears to be one great end of all the operations of infinite wisdom and omnipotence.

Thus it appears that the doctrine of a plurality of worlds is not only accordant with every rational view we ought to entertain of the eternity and immensity, the wisdom and goodness, of the Divine Being, but that the opposite opinion would be repugnant to every consistent and scriptural view we can take of the character of the Supreme, and would obscure the glory of every divine perfection. This view, therefore, of the universe, considered as replenished with innumerable intelligences, is calculated *to exhibit a more glorious and magnificent idea of the character and operations of the Deity* than to suppose his benevolent regards confined to the globe on which we dwell. Instead of having only one comparatively small world and race of beings under his sway, we here contemplate him as the supreme ruler of ten thousand times ten thousands of mighty worlds, and conducting them all, with unerring skill, in their vast career. We behold him exercising his moral administration over a vast *universe of minds*, more numerous than the faculties of men or of angelic beings are adequate to compute, supporting and directing all the amazing powers of thought, wisdom, intelligence, affection, and moral action, throughout every part of his eternal empire, displaying the depths of his wisdom and intelligence, the rectitude of his character, and the grandeur of his omnipotence to countless orders of intellectual existence, presenting before them prospects of magnificence and grandeur boundless as immensity, distributing among them all the riches of his beneficence, and inspiring them with the hope that the grandeur of his kingdom and the glory of his perfections will continue to be displayed with increasing splendour throughout all the periods of an endless duration. Such a Being is calculated to draw forth the highest degree of love and admiration from all his intelligent offspring, to inspire them with glowing ardour in his service, and to excite them to incessant adoration; whereas, did the universe consist merely of a boundless mass of matter without animation, thought, or intelligence, a veil of darkness and mystery would be thrown over all the perfections and purposes of the Divinity, creation would appear a vast, mysterious, and inexplicable system; and no hope would ever be entertained of tracing the designs for which it was brought into existence.

II. Another general argument for the plurality of worlds, and for an extensive population of the universe, may be founded on the following proposition,—that *wherever any one perfection of Deity is exerted, there also* ALL *his attributes are in operation*, and must be displayed, in a greater or less degree, to certain orders of intelligences. This is a most important consideration, which ought to be taken into account in all our views of the Divine character, and in all our investigations of the Divine administration—a consideration which is too frequently overlooked in the views and reasonings both of philosophers and theologians.

The Divine Being is ONE undivided essence; he is not compounded of *separable* parts or qualities, insulated from each other. We ought not, therefore, to conceive of his attributes as so many independent powers or properties, any one of which may be exerted without the concurrence or co-operation of the other. From the limited views we too frequently take of the Divinity, and from the imperfection of our present faculties, we are apt to fall into this mistake; but since all the perfections we attribute to the Eternal Mind are attributes of one indivisible and uncompounded Being, we ought never to imagine that *power* in any instance operates without *goodness*, or *wisdom* without *rectitude*, or that it can ever happen that any one of those perfections can be displayed without the harmonious operation of the whole. In whatever regions of the universe, therefore, God is seen to operate by his power, we may rest assured that there also he displays himself in the plenitude of all his other perfections; that intelligence, wisdom, benevolence, veracity, and rectitude follow in the train of omnipotence, displaying in undivided lustre and harmony the glories of his character. It is GOD, invested with all his eternal and immutable, his natural and moral attributes, and not any single perfection, that acts, arranges, and governs throughout the whole amplitude of creation; and as such, his moral grandeur, as well as the physical effect of his power, must be displayed in every department of the material universe. From the influence of habit, and in consequence of the limited faculties of our nature, we are accustomed to say, that in one object *power* is displayed, and in another that *wisdom* is manifested; because, that in the one the attribute of power appears to us most prominent, and in the other, wis-

dom is more strikingly apparent. A lofty range of mountains, rearing their summits above the clouds, and stretching along for several hundreds of miles, strikes the mind with an idea of *power* in Him who formed them; but the fine mechanism, accomplishing certain useful purposes in the body of an emmet or a gnat, or the delicate construction of the eye of a dragon-fly, arrests our attention more particularly as an evidence of *wisdom*, although in each of these cases both power and wisdom are displayed. In no act or operation whatever of the Divine Being can it be said, that in that act he is *only* wise, or only powerful, or only benevolent; for in every operation, and in every part of his procedure, he acts in the *plenitude* of all his essential attributes, although the full display of all his perfections may not, in every instance, be open to our inspection.

If, then, the positions now stated be admitted, (and I see not how they can be called in question,) it necessarily follows that all the vast globes dispersed throughout the universe are either inhabited or contribute, as our sun does, to the comfort and enjoyment of percipient existence; for if wisdom and goodness uniformly and of necessity accompany the agency of power, and if these attributes can be exercised only in relation to sentient or intelligent beings, such beings must exist wherever such perfections are exercised. To suppose the contrary would involve a palpable absurdity, and present a distorted and inconsistent view of the adorable character of Jehovah.

In our survey of the sidereal heavens, and the remoter provinces of the Divine empire, we behold little more than an overwhelming display of almighty power. Our remoteness from those magnificent scenes prevents us from tracing the minute contrivances of Divine Wisdom in relation to any particular system, or the displays of Divine Beneficence towards its inhabitants. But our incapacity in perceiving the effects of wisdom and goodness forms no arguments against the actual exercise of these perfections. If it be admitted that infinite wisdom and benevolence are the necessary accompaniments of almighty power, we may rest assured that those perfections are in full and constant exercise wherever creating power has been exerted, although, from our present situation in the universe, their operation be concealed from our view. In every instance where Omnipotence has put forth its energies, it may be considered as a stage or theatre on which the Divine wisdom and benevolence may be displayed. And as wisdom and goodness can only have a reference to percipient and intelligent beings, wherever those perfections are exercised, such beings must necessarily be conceived to exist; otherwise, we in effect destroy the *simplicity* of the Divine nature, we divide the Divine essence into so many independent attributes, and virtually declare that in the work of creation the Deity does *not* act in the full exercise of his indivisible and eternal perfections.

The above considerations, if duly weighed and understood, appear to me to embody an argument for the doctrine of an indefinite plurality of worlds which may be considered as amounting to a moral demonstration.

III. There is *an absurdity involved in the contrary supposition*—namely, that the distant regions of creation are devoid of inhabitants.

1. There are two modes of reasoning which have been employed to prove the truth of a proposition: the *direct* method, by bringing forward arguments, or following out a train of reasoning bearing expressly on the position to be supported; or the *indirect* method, by showing the absurdity of maintaining the opposite position. Mathematicians term this latter species of reasoning the *reductio ad absurdum*, and sometimes employ it instead of the direct method, by showing that the contrary of the position laid down is impossible, or involves an absurdity; and this method of proof is considered as valid, and as strictly demonstrative as the other; for the opposite of truth must be falsehood. If, therefore, any proposition, whether mathematical or moral, can be shown to involve an absurdity, or to be inconsistent with a well-known and acknowledged truth, or directly contrary to it, we may safely conclude that such a proposition must be *false*.

To feel the force of such an argument in the present case, let us suppose for a moment that the planetary and stellar orbs are destitute of inhabitants. What would be the consequences? All those vast bodies must then be considered as regions of eternal silence, solitude, and desolation. The sun illuminates the surfaces of such huge globes as Jupiter and Saturn, but there are no visual organs to perceive the lustre he throws around, no percipient beings to feel the influence of his heat and other benign agencies. Time is measured with exquisite precision by days, and months, and years, but all to no purpose; for no rational beings enjoy the advantage of such measures of the lapse of time, and the Deity—to whom "one day is as a thousand years, and a thousand years as one day"—stands in no need of such movements to mark the periods of duration. Day and night, spring and summer, succeed each other, but they have no relation to the wants or enjoyments of sensitive or intellectual natures. The melody

of the groves, the bleating of flocks, the lowing of herds, the harmonious accents of human voices, or the music of angelic choirs, never for a moment disturb the profound and awful silence which for ever prevails; not a single murmur meets the ear, unless howling winds, amidst dreary desarts and rugged rocks, should render the scene still more hideous and doleful. Some of those mighty globes are encircled with splendid rings and a retinue of moons, which adorn the canopy of the sky, and present a scene of grandeur far more diversified and sublime than human eyes have yet beheld, but no intelligent agents exist in those regions to admire and enjoy the wondrous spectacle and to adore the great Creator. In short, all is one wide scene of dreariness, desolation, horror, and silence, which would fill a spectator from this world with terror and dismay.

Were an inhabitant of the earth to be transported to Jupiter or Saturn, he might behold resplendent scenes in the canopy of the firmament; but how great would be his disappointment to find nothing but boundless desarts and desolate wastes, without one sentient being to cheer the horrors of the scene, and not a rational intelligence to communicate a single sentiment or to join him in the contemplation of the objects above and around him; and were he to range throughout an indefinite lapse of ages from one globe to another, and from one corner of the universe to another, and find the same gloomy solitudes and desolations, he could find no stimulus to excite him to admiration or rapture, or to elevate his soul in adoration of the Creator. Even the most resplendent scenes, adorned with all the riches and beauties which the most lively imagination can depict,—mountains of diamonds and plains diversified with all the beauties of the vegetable creation,—could impart no real pleasure while unenlivened with the principle of animation and the energies of *mind*. What a gloomy and horrible picture would such a scene present of the frame of universal nature, and what a veil of darkness and mystery would it throw over the perfections of the Eternal! for it is the scenes connected with life, animation, mental activity, and moral sentiment, glowing affection, social intercourse, and the mutual sympathies of intellectual beings, that can alone inspire the soul with rapturous emotions, throw a charm over any part of creation, and exhibit the Almighty Creator as amiable and adorable. It is chiefly from the relation in which the material world stands to sensitive and intellectual existence that its beauty and order are recognized and admired by contemplative minds, and that the wisdom and beneficence of the Deity are traced in all their minute and multifarious bearings. In our world, as it now stands, the arrangement of mountains and vales, the various properties of the watery element, and its transmutation into vapours, clouds, and dew, the admirable mechanism of the atmosphere, the fertility of the earth, and the beautiful colouring which is spread over the face of nature,—which are productive of so many beneficial effects, and so evidently display the wisdom of Deity,—would all appear as so many means without an end, as contrivances *without use*, if the earth were destitute of inhabitants. And if all the other departments of creation were likewise devoid of animation and intelligence, scarcely a trace would be left throughout boundless space of the wisdom and benevolence of the Eternal Mind.

2. In the next place, such a position as that which I am now opposing would be inconsistent with that principle of *variety* which appears so conspicuous throughout the whole range of the Divine operations, and with *that progressive expansion of intellectual views* which appears necessary to the perpetual enjoyment of immortal beings.

In order to permanent enjoyment it is necessary, from the very constitution of the mind, that one scene of happiness should succeed another,—that the soul should look forward to the future, to something *new* or more grand and expansive that it has yet beheld or enjoyed. It can never rest in present objects and attainments, but is always on the wing for something higher and more exquisite than it has yet grasped or enjoyed. What is the reason, in most cases, why *imprisonment* produces so doleful an effect upon the mind, but because its views and its actions are confined to a narrow circle? And if in such a situation newspapers, books, paper, pens and ink, be withheld, so as still further to circumscribe the mental view, its want of enjoyment and its misery are still more increased. Why would a literary man feel unhappiness had he no access to books, journals, and the periodicals of the day, nor any other means of information respecting passing events, but because he would thus be confined to his present range of view, and prevented from enlarging it? And why should the man who devours the periodical journal to-day feel as craving desires to-morrow to peruse similar records of intelligence, to mark the progress of passing events, but from the same vehement desire to expand his present intellectual views? Were such desires to remain ungratified, and the prospect of further information entirely shut up, a certain degree of misery would necessarily be felt by every rational mind. In another world, something similar would happen in the case of all intellectual

beings, were no new scenes and prospects ever unfolded to view.

Divines have generally admitted that the eternal world, in the case of the righteous, will be a state of perpetual and uninterrupted enjoyment. Such enjoyment, however, could never be realized, unless new scenes and objects, worthy of the admiration of exalted intelligences, were progressively displayed. But the contemplation of rude masses of matter, however vast in point of size and extent, and however magnificent in point of splendour, were they entirely unconnected with mind and moral action, would produce no high degree of enjoyment to beings possessed of capacious powers of intellect; for in such objects they could trace no evidences of skill or design, nor would they perceive any overflowings of Divine goodness to inspire them with gratitude and praise. We are warranted from Revelation to expect that in the future world the *knowledge* of good men will be indefinitely increased, in respect to their more enlarged conceptions of the Divine Being, and of his works and ways; that, among other subjects, they shall become more acquainted with the distant regions of creation, the destination of those great globes which we now behold at an impassable distance, the history of their inhabitants, the various stages of improvement through which they have passed, the most remarkable events which have happened among them since their creation, the relations which the different worlds bear to each other, the various orders of intellectual beings and their distinctive characteristics and endowments, with many other particulars which would afford an ample field of investigation and contemplation which could scarcely ever be exhausted, and a source of progressive and permanent delight. But all such prospects of knowledge and enjoyment would be for ever shut out, were the universe a collection of mere matter unconnected with mind or intelligence, and the distant view of an immortal existence would present little else than a scene of monotony or a boundless blank.

In the future world, although the circumstances in which the mind will exist will be different from its present local associations, yet its faculties, desires, and affections, will not be *essentially* changed. It will continue the same identical being, only transported to another region, and connected with other objects and associations. It will have the same or similar aspirations after happiness, the same desires after new objects and discoveries, and the expansion of its intellectual views, and the same delight in beholding one scene of creating grandeur after another unfolding itself to view, as it feels, in a certain degree, in the present state. Such desires after progressive improvement in knowledge and happiness are implanted by the Creator, and form an essential part of the constitution of the human soul, and therefore can never be eradicated so long as it is sustained in existence. But it is evident, from what has been already stated, that such desires could never be gratified, and that its expectations of higher degrees of intellectual expansion and enjoyment would be frustrated, were the scene of Omnipotence nothing more than an indefinite extension of matter without life or intelligence; for in such a case there would be little scope for the exercise and expansion of its powers throughout an immortal existence.

3. The supposition that matter throughout the universe is not connected with mind would present a distorted view of the character of the Almighty, and throw a veil over the most glorious perfections of his nature. It would virtually deprive the Creator of the attribute of *wisdom;* since no display of it would be perceived in the most magnificent works of his hands. It would, in effect, rob him of his *goodness;* since, throughout the mightiest and most extensive portion of his works, no enjoyment is communicated to beings endowed with either sensitive or rational natures, which are alone capable of being recipients of his bounty; consequently, no tribute of gratitude and thanksgiving would be offered, and no praises or adorations would ascend to the throne of the "King eternal, immortal, and invisible," from the greatest portion of his boundless dominions. It would prevent us from beholding any extensive display of the *rectitude* of his character and the equity of his government in the moral administration of the universe. Now, wisdom, goodness, and rectitude, can only be exercised in reference to intelligent natures, and cannot possibly be displayed where such beings have no existence.

The denial therefore of the position that the great universe is peopled with inhabitants, would lead us to contemplate a Being whose power has brought into existence a magnificent assemblage of means without an end; who has prepared glorious habitations fitted for the enjoyment of rational natures, but has never peopled them; who is the alone source of happiness, and yet refuses to communicate of his goodness where there is full scope for its exercise; and who is the Supreme Lawgiver and the spring of moral order, and yet affords no display of his moral attributes throughout the immensity of his works: for this earth, and all the beings that have ever been connected with it, are but as a drop to the ocean compared with the immensity of the material universe. Can it therefore be a

theatre of sufficient expansion for the display of the character and attributes of that being who has existed from eternity past, and will exist to eternity to come, and whose presence fills the amplitudes of boundless space?

If, then, such absurd consequences necessarily follow from maintaining the position, that there is no plurality of worlds, *that position cannot possibly be true.* It undermines truths of the first importance, which lie at the foundation of all consistent views of the character of the Deity, and which are acknowledged to be such by all rational theists and Christian divines. And, since what is directly opposed to truth must be error, and *vice versa,* it follows that the doctrine we are supporting must be considered as susceptible of moral demonstration; for it may be laid down as an axiom, that it is essential to the character of Deity that he act consistently in all parts of his dominions, that he display in every instance *all his perfections* in harmony, and that wherever his omnipotence has been exerted, there likewise he must display his wisdom, benevolence, and rectitude. Whatever opinion therefore directly tends to undermine or oppose such views of the Divine character and perfections must be absolutely untenable, and the opposite opinion must be indisputably true.

In my work on "Celestial Scenery" I entered on the consideration of several arguments which tend to prove the doctrine of a plurality of worlds, and that the planets of the solar system in particular are the abodes of intellectual beings. This position was illustrated at some length from the following considerations: that there are bodies in the planetary system of such *magnitudes* as to afford ample scope for myriads of inhabitants; that there is *a general similarity* among all the bodies of the system, which affords a presumptive evidence that they are intended to subserve the same ultimate designs; that, connected with the planets, there are certain *special arrangements* which indicate their adaptation to the enjoyment of sensitive and intellectual beings; that the scenery of the heavens, *as viewed from the surfaces of the larger planets and their satellites,* forms a presumptive proof of the same position; and that the fact *that every part of nature in our world is destined to the support of animated beings,* affords a powerful argument in support of this doctrine. These arguments and considerations, when viewed in all their bearings, and in connexion with the wisdom and goodness of the Divine Being, might be considered, without any further discussions, as quite sufficient to substantiate the position. that the planets and satellites of our system, as well as other departments of the universe, are the abodes of sensitive and intelligent beings.

In the preceding pages I have offered a few additional considerations bearing on the same point, which I trust will tend to corroborate the arguments and reasoning formerly adduced. I have shown that the doctrine of a plurality of worlds is more worthy of the perfections of the infinite Creator, and gives us a more magnificent idea of his character and works, than to suppose his benevolent regards confined to our comparatively diminutive world; that it is more accordant with the *infinity* and *eternity* of the Divine Being, and with his *wisdom* and *benevolence* than the opposite position; that wherever any one perfection of Deity is exerted, there also *all* his attributes are in operation; and consequently, wherever Omnipotence is seen to operate, there likewise, wisdom, benevolence, rectitude, and every other Divine perfection, must be displayed, and can only be displayed in reference to intelligent beings; that there is *an absurdity involved* in the contrary supposition; that this supposition would represent the universe as an immense desart, unworthy of the contemplation of intelligent minds; that it would prevent the progressive expansion of intellectual views in a future state, and present a distorted view of the character and attributes of the Almighty Creator. All these arguments and considerations, when viewed in a proper light, tend to yield a mutual support to each other, they hang together in perfect harmony, and they are in full consistency with the most amiable and sublime conceptions we can form of the Divinity; and therefore ought to carry irresistible conviction to the mind of every unbiassed and intelligent inquirer. To my own mind, they amount to *a moral demonstration;* so that I am as fully convinced of the truth of the position we have been maintaining, as if I were transported to the regions of distant worlds, and permitted to mingle in association with their inhabitants.

## CHAPTER XVII.

### *A Plurality of Worlds proved from Divine Revelation.*

It is somewhat difficult to persuade the greater part of mankind that there are any habitable worlds besides our own, or that rational beings, somewhat analogous to man,

may inhabit the planets of our own or of other systems. Even the greater part of Christians, and some who are possessed of a considerable degree of intelligence, can scarcely be persuaded that there are more worlds than one, or that the Divine government extends beyond the Christian church and the nations of the earth; and they attempt to vindicate their opinion by asserting, that the Scriptures never make the least allusion to any world except that in which we dwell. Although this were in reality the case, it would form no argument against the doctrine of a plurality of worlds; for the revelations contained in the Scriptures are chiefly of a *moral* nature, their great object being to counteract the depravity of man, and to afford information respecting the plans, and perfections, and moral government of the Divine Being, which the unassisted light of nature was unable to explore. They were not intended to teach us the principles of physical science, or the particular knowledge of any other subject which the human faculties were of themselves adequate to acquire; but to direct us, in all our surveys of the works of God, to look upward to him as the Supreme Agent, to trace his attributes in all his operations, and to offer him a tribute of grateful adoration. The Scriptures, therefore, would be fully sufficient to answer all the purposes of a revelation to man, although they made no allusion to other worlds, or to other intelligences within the range of the Divine government.

Since the system of nature, the system of revelation, and the rational faculties of man, had their origin from the same Almighty Being, we should naturally expect that they should perfectly harmonize in their grand lineaments, and in the truths they are calculated respectively to unfold; or, at least, that there should be no glaring contradiction between the intimations given by the one and by the other. If the investigations of reason in regard to the material universe necessarily lead to the conclusion that numerous worlds exist throughout immensity, and if the Scriptures contain a communication from God, we should never expect to find in that revelation any proposition asserting that there is only one world and one race of intelligent beings in the universe, and it is needless to say that no such proposition is to be found in the Bible. On the contrary, though the Scriptures never directly or explicitly treat of this subject, the doctrine of a plurality of worlds *is embodied in many passages of the sacred writings*; and the language of the inspired penman is in all cases perfectly consistent with the idea of myriads of worlds existing throughout the universe. To illustrate this position, in a few instances, is the object of this chapter; and as the passages of Scripture in which this sentiment is embodied are more numerous than is generally apprehended, I shall select only a few of them as the subject of comment and illustration.

The first passage on which I shall offer a few remarks is Psalm viii. 3, 4, "When I consider thy heavens, the work of thy fingers, the moon and the stars, which thou hast ordained; what is man, that thou art mindful of him! or the son of man, that thou visitest him!"

When composing this hymn of praise to God, the Psalmist evidently appears to have been contemplating, with intelligence and pious emotion, the glories of the nocturnal sky—the moon walking in brightness along the canopy of heaven, and the stars and planets diffusing their lustre from more distant regions. Viewing those resplendent orbs, his thoughts seem to have taken a flight into the regions of immensity, and by the guidance of his rational powers, and aided by the spirit of inspiration, he takes an expansive view of the multitude, the magnitude, and the grandeur of those magnificent orbs which roll in the distant tracks of creation. Overwhelmed with his views of the immensity of the universe, and of the perfections and grandeur of its Creator, he breaks out into this striking exclamation, "Lord! what is *man*, that thou art mindful of him! or the son of man, that thou visitest him!" Surveying with his intellectual eye the boundless extent of God's universal empire, he shrinks, as it were, into nothing, and seems almost afraid lest he should be forgotten or overlooked amidst the immensity of beings over which the Divine government extends. Now there could be no emphasis or propriety in this exclamation, if the inhabitants of this globe were the only rational beings that peopled the material universe; for, if man is the principal inhabitant of creation, it could be no matter of wonder and astonishment that God should be "mindful of him," and exercise towards him a special regard and superintending care. Such a minute attention and affectionate regard is nothing more than what we should have naturally expected. But, if the immensity of space be diversified with ten thousand times ten thousand worlds, replenished with rational inhabitants, as science and right reason demonstrate; if the race of Adam appear no more in proportion to the beings that people the amplitudes of creation than as a drop to the ocean, then the Divine condescension appears truly wonderful and astonishing, — that, from the heights of his glory in the heavens, the Most High should look down with an eye of com

placency on the puny inhabitants of earth, and regard them with a Father's attention and care. This is evidently the leading idea which the pious exclamation of the Psalmist is intended to convey; and therefore, if this globe were the only or the principal abode of rational beings, such language would be mere hyperbole, or something approaching to bombast, which would be inconsistent with the veracity and solemnity of an inspired writer.

It appears, then, that the passage under consideration is not only consistent with the doctrine of a plurality of worlds, but necessarily embodies in it the idea of the Divine empire being indefinitely extended, and comprising within its range numerous orders of exalted intelligences. It likewise teaches us, that while the Almighty has diversified the fields of immensity with innumerable worlds; that while he sits enthroned on the magnificence of his works in the distant regions of his creation, and governs the affairs of unnumbered orders of intellectual existence, *he also exercises the minutest superintendence over every world he has created*, however diminutive in comparison of the whole. His eye rests on the humblest and the minutest of its objects, and his Spirit watches over it as vigilantly as if it formed the sole object of his physical and moral administration; so that neither man nor the smallest microscopic animalculæ are overlooked amidst the multifarious objects of the Divine government. This is an attribute *peculiar to the Most High*, which flows from the immensity of his nature and the boundless knowledge he has of all his works, and which gives us a more glorious and sublime idea of his character than if his regards were confined to one department of his empire, or to one order of his creatures; and in nothing is the Divine Being so immensely separated from man, or from any other rank of intelligent existence, as in the display he gives of this wonderful and incommunicable attribute. By overlooking this peculiar characteristic of the Divinity, and attempting to compare his procedure with the limited conceptions of our own minds, we are apt to indulge in very contracted and erroneous views respecting his nature and universal government, as well as in regard to the revelations of his word and the dispensations of his providence.

The next passage I shall notice is Isaiah xl. 15, 17. "Behold, the nations are as a drop of a bucket, and are counted as the small dust of the balance." "All nations before HIM are as nothing, and they are counted to him less than nothing and vanity."

In the chapter from which these words are taken, the prophet announces deliverance from the captivity of Babylon, and the approach of that period when "the glory of Jehovah shall be revealed, and when all flesh shall see it together."—In order to obviate every difficulty that might seem to stand in the way of the accomplishment of such a glorious event, the prophet describes, in the most sublime language, the perfections and character of him by whose agency this astonishing change in the world was to be introduced. He is declared to be that Almighty Being "who measures the ocean in the hollow of his hand, who meteth out the heavens with the span, who comprehendeth the dust of the earth in a measure, and weigheth the mountains in scales, and the hills in a balance." The prophet likewise denounces the folly and wickedness of idolatry, by exhibiting the character and operations of him whom no material images, however splendid, can ever represent or adumbrate. "He sitteth on the circle of the sky which surrounds the earth, and the inhabitants thereof are as grasshoppers; he stretcheth out the heavens as a curtain; he bringeth forth their host by number; he calleth them all by their names, by the greatness of his might; for that he is strong in power, and there is no searching of his understanding." Among these sublime descriptions are contained the passages I have quoted,—"Behold, the nations are as the drop of a bucket." "All nations before him are as nothing," &c. Such declarations could scarcely be made with propriety, if all the rolling orbs of heaven were destitute of inhabitants; for then it would not be true that "all nations are as the small dust of the balance," and that they are "counted to Jehovah as less than nothing and vanity." They who deny the doctrine of a plurality of worlds assume the position, "that man holds the principal station in the material universe;" but were this the case, then the nations of the earth, and "their multitude and glory," behoved to be considered as the greater portion, or as one of the greater departments of the Divine empire; and if so, it would be approaching to extravagance and bombast for any one to declare that they are only like a drop campared with the ocean, like a few particles of dust compared with a mighty island, or, in comparison with other departments, that "they are as nothing, and less than nothing and vanity."

We are here to consider the comparisons and contrasts drawn in those passages as referring, not to Jehovah, abstractedly considered, but to the *manifestations* he has given of his power, wisdom, and grandeur, in the scenes of the universe. Hence we are directed in the chapter from which our quotations are taken, to "lift up our eyes on high,"

and contemplate "the firmament of his power;" to "behold the hosts" of resplendent globes which he has dispersed throughout the regions of space "by the greatness of his strength," and to consider that the vast extent of the celestial spaces have been "meted out with a span." When the inspired writers demand from their hearers a sentiment of reverence and admiration, they do not present to them metaphysical reasonings or abstract views in reference to the perfections of Jehovah, but describe those exhibitions of his power and grandeur which are calculated to strike the senses and imagination, and to excite the emotion intended. Thus, when the prophet Jeremiah wished to impress his hearers with a reverential sense of the greatness of God, he describes him by the *effects* of his power and wisdom as displayed in his operations. "Who would not fear thee, O King of nations! He hath made the earth by his power, he hath established the world by his wisdom, and hath stretched out the heavens by his discretion. When he uttereth his voice, there is a noise of waters in the heavens, and he causeth the vapours to ascend from the ends of the earth; he maketh lightnings with rain, and bringeth the wind out of his treasures."

In like manner, in the passages under consideration, we are to consider the contrast here stated as drawn, not between all nations and Jehovah as an abstract Being, whose perfections are infinite; for in this respect no comparison can be made, but as drawn between this earth with all its inhabitants, and the innumerable globes which are scattered throughout the regions of immensity. And the most enlightened astronomer, after his boldest excursions into the illimitable tracks of creation, could devise no language to express his emotions, and the contrast that subsists between this globe and the immensity of the heavens, more appropriate and energetic than the passage before us. This world, with "all that it inherits," is here represented as a single drop of water to the mighty ocean, or as a few particles of dust to the most spacious continents, when compared with the grandeur and immensity of nature; yea, to complete the contrast, it is "counted as nothing, and less than nothing and vanity." When we survey the vast globes which compose the planetary system; when we wing our flight in imagination to the starry regions, and leave the sun and all his attendants behind us, till they dwindle to an undistinguishable point; when we prosecute our course through thousands of nebulæ, every one of them containing unnumbered suns and systems; and when the mind is bewildered and overpowered at the immensity of the prospect, we cannot but perceive that the language of the prophet is the most impressive, and the fittest that could have been selected; that it is most emphatic, and literally true. But if this earth were the principal part of God's universe, there could be no propriety in such language, and it could be considered as allied only to extravagance and pompous declamation—a characteristic which ought never to be applied to the writers of the sacred records.

We ought likewise to consider that the contrast is not stated between the earth considered merely as a *material system*, and the amplitudes of the firmament, but between *the nations of the earth* and the innumerable order of beings which people the universe; plainly implying, in my apprehension, that unnumbered myriads of intelligences occupy the celestial worlds, in comparison of which all who now dwell upon the earth, or who have occupied its surface since time began, are only as a drop to the ocean. The passage before us may therefore be considered as almost a direct intimation of a plurality of worlds; and, if it could be proved that no other worlds existed, I should scarcely consider the strong language here used as the dictate of inspiration; but when we consider what appear to be the true references of the prophet's language, and the magnificent ideas it suggests, it conveys the most glorious and sublime conceptions of the grandeur of "the high and lofty One who inhabiteth eternity," and whose presence fills the immensity of creation.

The next passage I shall adduce in support of the position under consideration, is Nehemiah, ix. 6: "Thou, even thou, art Lord alone; thou hast made heaven, the HEAVEN OF HEAVENS, with all their host, the earth, and all things that are therein, the seas, and all that is therein, and thou preservest them all; and the HOST OF HEAVEN worshippeth thee."

Here the Most High is represented, not by a metaphysical exhibition of his infinity, eternity, and omnipotence, abstractedly considered, but by the *manifestations* he has made of himself in his wonderful operations, both in heaven and on earth; and this is the general, I may say universal, mode in which the sacred writers exhibit the character and perfections of the Deity. "Thou hast made heaven, the heaven of heavens, with all their hosts." By "heaven" is here to be understood the visible firmament, with all the stars and planets perceptible by the human eye, which is the sense in which the term heaven is generally taken when God is represented as its Creator. The "heaven of heavens" is an expression which is worthy of particular attention, and evidently includes in it an idea

far more extensive and sublime than what most readers generally attach to it. It evidently intimates that, far beyond the visible starry heavens which we behold, there are unnumbered firmaments, composed of other stars and systems stretching out towards infinity on either hand, and which mortals in their present state will never be able to descry. We have already attained some glimpses of such firmaments. More than a hundred millions of stars, in addition to those distinguishable by the naked eye, are within the reach of the telescope, if all the regions of the sky were by this instrument thoroughly explored. We behold several hundreds, and even thousands, of *nebulæ* in different spaces of the heavens, each of them consisting of thousands of stars, which would form a firmament as glorious and expansive as that which appears to a common observer in the midnight sky; so that were we removed from one of those nebulæ to another, we should behold at every stage a new firmament, composed of stars or other luminaries altogether different from what we had seen before, or from what we perceive in the firmament which is visible from our globe. These facts, which have been brought to light by the discoveries of modern astronomy, while they display the infinite power and grandeur of the Divinity, serve likewise to illustrate many of the declarations of his word, and particulary such expressions as that before us,—"the heaven of heavens," the boundless empire of the "King eternal and invisible," in which he reigns over unnumbered intelligences. The same emphatical expression is used in the prayer of Solomon at the dedication of the temple: "But will God in very deed dwell on earth? Behold, the heaven and heaven of heavens cannot contain thee!" implying that far beyond the range of the material universe, vast and extensive as it is, the great Jehovah resides in the glory of his invisible attributes, filling immensity with his presence.

By "*the host of heaven*" is doubtless to be understood the inhabitants of those numerous worlds and vast regions here designated by the most emphatic expression which could be selected, "the heaven of heavens;" intimating that the same Almighty Being who launched into existence those innumerable globes also replenished them with countless orders of intelligent existence, capable of enjoying his bounty, and offering to him a tribute of adoration. Hence it is here declared, "the host of heaven *worshippeth* thee;" evidently implying, if there is any rational idea to be elicited from the passage, that the bodies which compose "the heaven of heavens" are occupied with inhabitants; that these inhabitants are endowed with capacious powers of intellect; that their numbers correspond with the amplitude of the regions which they occupy; that most, if not all of them, are invested with the attribute of moral perfection, and are consequently in a state of happiness; that they employ their faculties in contemplating the perfections and operations of their Creator; and that they magnify and adore him in the loftiest strains, as the centre and source of all their felicity: all which appears to be implied in the passage, "the host of heaven worshippeth thee." For no being can with propriety be said to worship Jehovah, unless such as are endowed with moral and intellectual powers, capable of appreciating his perfections, as displayed in the universe, and of perceiving that he is worthy of all homage and adoration. In accordance with such views the Psalmist, when his soul was inspired with the higher strains of devotion, in a sublime apostrophe, calls upon the whole intelligent universe to adore the name of Jehovah:—"Praise ye Jehovah from the heavens; praise him ye heaven of heavens,"—or, ye *inhabitants* of those higher regions,—"praise him, all ye his angels; praise him, all ye his hosts. Let them praise the name of the Lord, for his name alone is exalted, and his glory is above the earth and heaven." If therefore there were no other worlds than that on which we dwell, such magnificent expressions would lose all their sublimity, would be almost without meaning, and might be regarded rather as the turgid exclamations of an enthusiast than as the sober dictates of inspiration. But when we take into view the immensity of the universe, and the numerous worlds and beings it contains, such expressions, though among the strongest which human language can furnish, fall far short of communicating the lofty ideas they are intended to represent.

Such passages as the following may likewise be considered as embodying views of the same description:—Psalm ciii. 19,—"The Lord hath prepared his THRONE in the heavens; and his kingdom ruleth over all."

This, along with a number of similar passages interspersed throughout the Scriptures, evidently implies that *the heavens* form the principal part of the Divine empire, compared with which, this earth is but as a point, and "all its inhabitants reputed as nothing." They are represented as the chief and appropriate residence of Jehovah, where he displays the glory of his perfections to unnumbered intelligences. Hence he is declared to have "*established his throne* in the heavens," intimating, that it is in those higher and more expansive regions that the principal arrangements of his government have been made, that the beneficence and rectitude of his character are manifested, and that the grandeur

of his moral administration is most extensively displayed. But it is evident, that where there are no intellectual beings, there can be no moral government; and therefore, if the Almighty has a government in the heavens, these heavens must be peopled with beings endowed with moral and intellectual faculties, capable of being the subjects of a moral administration. To suppose a government without subjects, is evidently preposterous and absurd. It is added, "His kingdom ruleth over all." Wherever these expansive heavens extend, and however numerous and august the worlds and systems which lie within their range, they are all under the superintendence and sway of the Divine government, which extends its care and moral energies over the remotest regions of the universe. But as there can be no kingdom without rational and moral subjects, therefore, wherever the kingdom of Jehovah extends throughout the illimitable spaces of immensity, there must be myriads of beings endowed with rational and moral natures. Similar remarks might be made upon such declarations as the following:—"The Lord, he is *God* in the heaven above," intimating his rule or dominion over the worlds on high: "Behold the heaven and the heaven of heavens is the Lord thy God's," intimating, likewise, that he presides in high authority over all the beings they contain; "Thine, O Lord, is the greatness, and the glory, and the majesty; for all in heaven and in earth is thine. Thine is the kingdom, O Lord, and thou art exalted above all;" "Heaven is my *throne* and the earth is my footstool;" "His kingdom is an everlasting kingdom;" "His dominion is an everlasting dominion;" and "He doth according to his will *in the army of heaven*, and among the inhabitants of the earth." All these, and similar passages, imply *rule* and *dominion* over the inhabitants of the heavens; and consequently intimate that the celestial worlds are occupied by the subjects of the divine government. It is not improbable that the expression which so frequently occurs in scripture, "*The Lord of hosts*," or the Lord of armies, has a particular reference to the universal dominion of Jehovah over the countless myriads which people the distant regions of creation.

Psalm cxlv. 9: "The Lord is good to all; and his tender mercies *are over all his works*."

The goodness of God, in innumerable modes and instances, is displayed, not only towards man, but to all the diversified orders of animated existence in this lower world. But it is not confined to this terrestrial sphere, but is diffused wherever his wisdom and omnipotence have prepared habitations for sensitive and intellectual beings. Hence it is here declared, that "his tender mercies," or the emanations of his goodness and beneficence, "are diffused *over all his works*;" implying that throughout the whole range of the material system, however far it may extend, the beneficence of the Deity is displayed to numerous ranks of his sensitive and intelligent offspring; for unless such beings exist throughout all places of his vast dominions, there could be no scope for the exercise of his benevolence, and of course it could not be said, with propriety, to extend "over *all* his works." In the same point of view we may consider an analogous expression in Psalm cviii. and other places of Scripture,—"Thy mercy is great above the heavens;" or, as Mr. Locke translates it, "Great is thy BOUNTY *above the heavens*;" an expression which leads us to conclude, that far beyond these visible heavens which the unassisted eye beholds, and even beyond the reach of all the orbs which the telescope has enabled us to descry, the Divine goodness shines in rich manifestations, diffusing felicity and ecstatic joy among unnumbered legions of happy existence; for "bounty," or "goodness," can have a relation only to such beings.

In the following passage of Psalm cxiv. 10—13, it is declared, "All thy works shall praise thee, O Lord, and thy saints shall bless thee. They shall speak of the glory of thy kingdom, and talk of thy power; to make known to the sons of men his mighty acts, and the glorious majesty of his kingdom. Thy kingdom is an everlasting kingdom," &c.

This passage may be considered as embodying a prediction that in the future ages of the church men of piety will acquire more elevated and comprehensive views of the extent and the grandeur of the universal kingdom of Jehovah, and will display a more enlightened zeal than in ages past, in exhibiting to their fellow-men the august operations of Omnipotence, and the magnificence of that empire over which the Most High presides. "They shall speak of the glory of Jehovah's kingdom, and talk of his *power*." If this kingdom were chiefly confined to the evanescent speck of earth on which we live, it would scarcely be worthy of the epithets which are here bestowed upon it. It is a kingdom of GLORY: it is a kingdom in which are displayed *mighty acts* or operations; it is a kingdom of *glorious majesty*; it is a kingdom in which are displayed "power," and "*greatness which is unsearchable*;" it is a "kingdom of all ages," and its administration will be carried forward throughout all the revolutions of eternity—"thy kingdom is an *everlasting* kingdom." Were its government conducted chiefly in reference to earth and its inhabitants, such descriptions of

its grandeur could scarcely be expected from inspired writers, nor would such a limited kingdom correspond to the majesty of an infinite omnipotent, and eternal Being, who has the range of immensity as the theatre of his operations. But when we contemplate the universal kingdom of Jehovah extending throughout the unlimited regions of space; when we behold it filled with worlds of immense magnitude, and with systems of worlds in such a multitude and variety that no man can number them, we perceive at once that such a kingdom warrants the application of such lofty epithets and expressions as are here used; that it is indeed a kingdom displaying omnipotent "power," and "greatness unsearchable;" that it is connected with "mighty operations;" that it is invested with "glorious majesty;" and that it is worthy of everlasting duration. But as the idea of a kingdom necessarily includes *subjects*, and as the multitude of subjects constitute the chief glory of an empire, so we must necessarily admit that all the provinces of this celestial kingdom are replenished with inhabitants, or in other words, *subjects* of the Divine government; without which it could have no "glory" nor "majesty," nor could it with propriety be entitled to the designation of "a kingdom."

Such passages as the following may likewise be considered as corroborating the preceding positions: Psalm cxiii. 4—6, "Who is like unto the Lord our God, who dwelleth on high? The Lord is high above all nations, and *his glory above the heavens.* He humbleth himself to behold *the things that are in heaven* and in the earth." "Thy goodness is great above the heavens, and thy truth reacheth to the skies. Thou art exalted, O God, *above the heavens*," &c.

These passages, and others of a similar import, embody the general idea that the omnipotence and grandeur of the Divinity are displayed in regions far beyond that firmament which is visible from our globe by common observers, yea, beyond the utmost limits to which telescopic discoveries have conducted us; for "his glory is *above*," or beyond, "these heavens." And if nothing but empty space existed beyond these limits, or mere matter without mind, it could scarcely be said that the Divine *glory* is displayed beyond these heavens. It is further stated that the glory of the Almighty is so expansive, and that his universal kingdom extends through regions so immeasurably distant that he may be said, speaking after the manner of men, "to *humble himself* when he beholds *the objects in the heavens*" which lie within our observation. This declaration contains not only a sublime representation of the magnificence of the Divine nature and operations, but appears to me to embody in it a demonstration of what we formerly asserted as highly probable—namely, that that portion of the universe which lies within the range of telescopic vision, and which contains so many millions of splendid suns and systems, is but a *small part* of the universal kingdom of Jehovah, compared with what lies beyond the utmost boundaries of human vision; for he is here represented as *humbling* himself when he looks down from the remoter glories of his empire on all that is visible to the view of mortals. To the same purpose is the pious exclamation of the Psalmist in the 8th Psalm: "O Lord, our Lord, how excellent is thy name in all the earth! *who hast set thy glory above the heavens!*" And if the glory of the Divinity, be manifested in regions far beyond the visible firmament, we may rest assured that it consists in displaying his perfections, and communicating happiness to innumerable orders of rational beings, who are the subjects of his moral government.

I shall only further offer a few cursory remarks on the following passages:—Psalm xix. 1, "The heavens declare the glory of God," &c. The word *glory* in this and similar passages, when applied to the Divinity denotes the display of his wisdom, goodness, omnipotence, and other attributes. The heavens, with all the host of rolling orbs which they contain, are here declared to manifest the "glory," or the infinite perfections, of Him who formed them. The number and magnitude of the opaque and luminous globes contained within the vast expansion of these heavens, and their astonishingly rapid motions, evidently proclaim his *omnipotence;* but if those bodies accomplished no end corresponding to the extent and grandeur of the means employed; if they were all so many expansive desarts, without any relation to intellectual existence, they could afford no evidences of wisdom and beneficence, and consequently could not be said, with any show of reason, to "declare the glory of God." In the visions recorded in the Book of Revelation, the celestial inhabitants are represented as falling down before the throne of the Eternal in acts of adoration, and proclaiming, "Thou art worthy, O Lord, to receive glory, and honour, and power; for thou hast created all things." And in another scene they are introduced as celebrating with rapture the Divine operations: "Great and marvellous are thy works, Lord God Almighty." "Blessing, and glory, and wisdom, and thanksgiving, and honour, and power, be unto our God for ever and ever." Similar remarks to the above might be made in reference to these ascriptions of praise and adoration. If creation were a kind of chaos, or wilderness void of inhabit-

nts, and if wisdom, design, and goodness were not displayed in the Divine arrangements, there would be little to excite the *admiration* and devotional rapture of superior intelligences; and they could not be said with propriety to ascribe *wisdom*, and glory, and thanksgiving to God, while they beheld no display of some of these attributes in the mightiest of his works. But we are told in various passages of Scripture that the Most High "established the world," or the universe, "by his wisdom, and stretched out the heavens by his understanding." In Psalm cxlvii. 4, it is declared—"He telleth the number of the stars; he calleth them all by their names." It is evident that we are not to consider this declaration as expressive merely of an arithmetical idea, or something similar to the practice of an astronomer, who distinguishes the stars by certain letters, characters or appellations; but as expressive of the intimate knowledge which the Almighty has of all those mighty orbs wherever dispersed throughout the regions of infinitude, and likewise his perfect acquaintance with all the intellectual beings, and the special arrangements connected with every one of them—a circumstance which conveys a most sublime idea of the omniscience and omnipresence of the Deity. Hence, in the words immediately following, the mind of the Psalmist, overpowered with this idea, bursts forth in this exclamation, "great is our Jehovah, and of great power; his understanding is infinite."

In the epistle to the Hebrews, chapter i. 2, and xi. 3, a plurality of worlds is declared: "Through faith we understand that *the worlds* were framed by the word of God, and that the things which are seen were not made of things that do appear." The Greek word, αιων in this passage, is sometimes used to denote *an age* or *dispensation*, but is also frequently used to designate the material world; in which sense it must be taken in the passage before us, as is evident from its connexion, and from the subject on which the apostle is treating. It is to the visible or material world that our attention is here directed as having been produced from an invisible cause. The term αιωνας being used in the plural number, evidently intimates that there are more worlds than one, and that there may be thousands or millions; but, independently of this direct intimation of a plurality of worlds, the passages formerly quoted, when viewed in a proper light, and considered in all their references and bearings may be considered as conclusive proofs of the same position, and as intimating to us, not simply a plurality of worlds, but extending our views of their number and magnificence as far as science has yet conducted us, and even beyond the range of astronomical discovery; for we are told that the Divine perfections are displayed "above," or beyond, the utmost range of "the visible heavens."

Many other passages besides the above might have been pointed out as bearing on the same subject, but the remarks already made on the passages which have been selected may serve as a key to illustrate many others, as they happen to occur to the intelligent student of the Scriptures. We read, for example, of the Almighty "operating, by his moral government and arrangements," "among the army," or armies, "of heaven," as well as "among the inhabitants of the earth;" and that the whole population of our world "is reputed as nothing in his sight." We find in different portions of the Psalms, the inhabitants of the heavens, and "the heaven of heavens"—the "angels who excel in strength"—"all his hosts," or legions, of intelligences, "in all places of his dominions, who do his pleasure, hearkening to the voice of his word,"—we find all these ranks of beings called upon to join in one united chorus of praise and thanksgiving to "Him whose name alone is exalted, and whose glory is above the earth and heaven." We read in the Book of Job, among many other descriptions of the grandeur of the Deity, that "by his Spirit he garnished the heavens;" and that the astonishing displays of his omnipotence they contain "are but parts of his ways," and that "the thunder of his power none can understand." All of which representations, and many others, may be considered as embodying the idea, not only of a plurality, but of myriads of worlds existing in the universe.

There is one general remark which may be applied to all that we have stated in this chapter, and that is—*It is not necessary to suppose that the inspired writers had revealed to them all the wonders of modern astronomy.* They appear, in some instances, to have been ignorant of the precise meaning and the extensive references of the language they used. The prophets are said to have "inquired and searched diligently what manner of time the spirit of Christ which was in them did signify, when it testified beforehand the sufferings of Christ and the glory that should follow;" intimating that they were partly unacquainted with the precise references of the predictions they uttered. They were only the *amanuenses* of the Divine Spirit, and were directed to such language as was accordant with the Divine economy and with the facts existing in the universe, although they themselves might not be aware of the grandeur of those objects to which their expressions referred; and the correspondence

of their language with the phenomena of the heavens and the earth, and the discoveries of modern times, constitutes one evidence among others of the truth of Divine revelation

## CHAPTER XVIII.

### *On the Physical and Moral State of the Beings that may inhabit other Worlds.*

On the enunciation of this topic, some readers will, probably, be apt to surmise, that the author is attempting to go beyond the range of subjects within which the human understanding should be confined. We have never seen the inhabitants of other worlds; we have been favoured with no *special* revelations respecting them; we have not even caught a glimpse of the peculiar scenery of the globes in which they reside, excepting a few portions of their celestial phenomena; and while we are chained down by the law of gravitation to this sublunary sphere, we cannot fly on the wings of a seraph to visit any of the distant orbs of the firmament. It is true, that on such a subject we cannot attempt to descend into particulars. But there are certain general and admitted principles on which we may reason, and there are certain phenomena and indications of design exhibited in the structure of the universe from which certain general conclusions may be deduced; beyond such generalities I do not intend to proceed, nor to indulge in vague conjecture. There are many things of which we have acquired a certain degree of knowledge, and yet have never seen. We do not see the air we breathe, nor most of the gaseous fluids; we do not see the principle of life, or the rational spirit which animates our bodies; we cannot possibly see the Divine Being, although his presence pervades all space. But, in regard to all these objects, we have acquired a certain degree of information; and therefore, although we have never seen any of the inhabitants of other planets, and never will so long as we remain in our present abode, yet we may form some general conceptions respecting them, both as to their physical and moral state. All that I propose on this point may be comprehended under the following general remarks:

1. The planets, wherever they exist, in our own or in other systems, are inhabited by *sentient beings*. The formation of *material* fabrics, such as all the planetary bodies are, necessarily indicate that beings connected with *material* vehicles and organs of sensation were intended to inhabit them. The arrangements for the diffusion of light, heat, and the influence of the power of attraction, and other material agencies, evidently show that such agents were intended to act on beings formed with organical parts and functions, capable of being the recipients of impressions from them. All such beings, therefore, must be considered as furnished with bodies constructed with organical parts *analogous* to what we find in man or other animated beings on our globe; but the size and form of such bodies, the parts of which they are composed, the functions they respectively perform, their symmetry and decoration, and their powers of locomotion, may be very different from those which obtain in our sublunary world; and it is not unlikely, from a consideration of the *variety* which exists in the universe, that there is a certain difference, in these and other respects, in every planet and world that exists throughout immensity.

2. The principal inhabitants of the planets and other worlds are not merely sensitive beings, but are likewise endowed with *intellectual faculties*. This may be inferred from the scenery connected with their habitations. Connected with the planet Jupiter, we behold four splendid moons, larger than ours, performing their revolutions around it *in regular periods of time*, without the least deviation from their courses. The general aspect of these moons, their diversified phases and rapid changes, along with their frequent eclipses, must produce a sublime and variegated appearance in the nocturnal sky of that planet; while, from the surface of the moons themselves, the still more splendid appearance of Jupiter and the phases of the other moons will present a nocturnal scene of peculiar sublimity and magnificence. Connected with the planet Saturn, we find scenes still more august and diversified; besides seven large moons, two resplendent rings of vast extent surround the body of this planet, producing the most sublime and diversified phenomena, both to the planet itself and to all its satellites, adorning the firmaments of those bodies with a splendour and magnificence of which we can form but a faint conception.* Were we permitted minutely to inspect the surfaces of these planets, we should doubtless find many beautiful arrangements in the scenery of nature with which they are adorned, probably far surpassing in picturesque variety and

* For a particular description of the scenes here alluded to, the reader is referred to "Celestial Scenery, chap. viii.

grandeur what appears on the surface of our globe. When we inspect the surface of the moon through a good telescope, we behold a beautiful diversity of extensive plains, of lofty mountains, in every variety of size and form—of plains and valleys surrounded with circular ramparts of hills—of mountains towering far above, and vales and caverns sinking far below the general level of the lunar surface, with many other varieties; and we have only to suppose the general surface of that orb adorned with vegetable productions somewhat analogous to those of our globe, in order to present a sense of picturesque beauty and magnificence.

Now, it appears a natural, if not a *necessary* conclusion, that such grand and beautiful scenes could only be intended for the contemplation and enjoyment of beings endowed with rational natures, since mere sentient beings, such as the lower animals in our world, are insensible either to the beauties of the vegetable kingdom or the glories of the spangled firmament. If our globe had been created merely for the support of such beings, it is not probable that it would have been adorned with all the beautiful arrangements which now exist, and the splendid and diversified scenes with which it is furnished. The lion, the tiger, and the hyena find every accommodation they desire in dens, deserts, thickets, and forests; and they appear to feel no peculiar enjoyment in flowery fields, expansive lakes, beautiful landscapes, or the sublimities of a starry firmament. If, then, there were no rational intelligences in the planetary worlds, we cannot suppose that so many grand and magnificent arrangements as we find existing would have been made; particularly, we cannot suppose that the motions of the planets and their satellites would have been so accurately adjusted as to perform their revolutions with so much precision as we find they do. The regularity and precision of these motions are evidently intended to serve as accurate measures of *time* or duration,—a circumstance which must always be a matter of importance to rational beings wherever existing, but which seems to be scarcely attended to, and perhaps not in the least appreciated, by merely sentient beings, such as the lower orders of animated nature which exist around us.

From what has been now stated, we may conclude that the inhabitants of the planets are not *purely spiritual* beings; for pure spirits, entirely divested of material vehicles, cannot be supposed to have a permanent connexion with any material world or system; nor could they be supposed to be affected by air, light, colours, attraction, or other material influences, which operate on the surfaces of all the planetary bodies. If pure intelligences, disconnected with matter, exist in the universe, they must be conceived to have a more expansive range than the limits of any one globe, and those material agencies which affect the organs of sensitive existence cannot be supposed to operate upon them: and, consequently, their modes of perception must be altogether different from those of organized intelligences. We may therefore with certainty conclude that the intelligent beings connected with the planetary worlds, either of our own or of other systems, are furnished with *bodies*, or corporeal vehicles of some kind or other. These may differ in size and form in different planets; perhaps their size may depend on the amplitude of space which the different planets may contain. But I cannot acquiesce in a supposition lately thrown out by a certain reviewer, "that in some worlds the inhabitants may be as large as mountains, and in others, as small as emmets." In the one case, comparatively few inhabitants could live in a world where every one was a walking Mount Blanc or Mount Etna; and it would be contrary to all the known arrangements of the Creator; who appears to act on the principle of compressing into a small space the greatest degree of sensitive and intellectual enjoyment. Besides, such a huge mass of matter as a mountain is not only unnecessary, but in all probability would be highly injurious to the exercise of the intellectual faculties. In the other case, were rational beings as small as emmets, they could neither contemplate the beauties and sublimities of the scene of nature around them, nor the glories of the starry firmament; their range of vision could extend only a few feet or yards around them, and they never could be able to explore the nature, extent, and peculiarities of scenery of the world they inhabited. So that all such suppositions are evidently extravagant and absurd, being directly contrary to the proportion and harmony which exist in the universe, and which characterize all the arrangements of the Creator. In regard to the powers of locomotion, there may be considerable differences in different worlds. In many instances there is reason to believe their inhabitants are enabled to transport themselves from one region to another with a velocity far surpassing the locomotive powers of man. In the planet Venus some of the mountains are reckoned to be twenty-two miles in perpendicular elevation, from the top of which eminences the most sublime and diversified prospects must be enjoyed; and in order that its inhabitants may be enabled to ascend with ease such lofty elevations, it is not unreasonable to believe that they are endowed with powers of

motion far superior to those of the inhabitants of our globe.

3. The inhabitants of the planets are furnished with organs of sensation, particularly with *the organ of vision.* This may be certainly deduced from the fact, that there are connected with the planets arrangements for the equable *distribution of light.* The sun, the source of illumination, is placed in the centre of the system for diffusing light in certain proportions over the surfaces of all the planets, their satellites, and their rings. Each planetary body revolves round its axis, in order that every part of its surface may alternately enjoy the benefit of the solar radiation. Around the larger planets are moons for the distribution of light in the absence of the sun; and one of them is invested with a double ring, which reflects the solar rays during the night both on the surface of the planet itself and on the surfaces of its moons. This diversified apparatus for the diffusion of light evidently appears to be an arrangement of *means* in order to the accomplishment of an important *end;* for it would be a reflection on the character of the All-wise Contriver to suppose that means have been arranged where no appropriate end is intended to be accomplished; but all the arrangements for the regular and equable diffusion of light have been made in vain, if there be no *eyes* or organs of vision on which light may act; for mountains, and vales, and barren desarts do not require its regular influence. That there are beings furnished with visual organs throughout all the worlds and systems of matter in the universe appears from the consideration, that not only in our own system, but among the myriads of fixed stars dispersed throughout immensity, provision is made for such organs in the existence of *light,* which is a substance that appears to be universally diffused throughout creation. It is found by experiment, that the light which radiates from the most distant star is of the same nature as that which emanates from the sun. It is refracted and reflected by the same laws, and consists of the same colours, as that which illuminates the bodies which compose the solar system, and which throws a lustre on the objects immediately around us. The mediums of vision must therefore be acted upon by light, in the most distant regions of creation, in nearly the same manner as with us, although there may be numerous varieties and modifications of the visual organs, so as to render vision far more perfect and extensive than in the case of the inhabitants of our globe. We find that there is an immense variety in the modes of vision among the lower animals. Some of the smaller insects have their eyes nearly of a globular form and very small, so that they can see only a few inches around them; while the eyes of other animals, such as the eagle, are so constructed that they can perceive their prey at a great distance, and from a very elevated position. Some animals have only one or two visual organs or eye-balls, as man, birds, and quadrupeds; others have eight, as in the case of spiders: and others have several hundreds, and even thousands, of transparent globules, each of which is capable of forming a distinct image of any object, as is the case with flies, butterflies, and other insects. All these diversified constructions of the organs of vision, however, perform their functions according to the same invariable laws of optics.

But although light must act on the eyes of all organized beings in a manner somewhat similar, or at least analogous to what it does on our organs, yet there may be certain configurations of the organ of vision by which a more glorious and extensive effect is produced than by the human eye. The inhabitants of some other worlds, instead of being confined in their range of vision as we are, may be able to penetrate through space to an indefinite extent, and to perceive with distinctness all the prominent objects connected with neighbouring worlds; and even the peculiarities of distant suns and systems may be within the range of their view. The *difference* between the eye of an insect, which sees only an inch or two around it, and the eye of a man, which can grasp at once an extensive landscape, is perhaps as great as the difference between the vigour and extent of human eyes and such organs of vision as I have now supposed. And who shall set boundaries to the mechanisms of infinite wisdom, especially when we consider the varieties which exist in our terrestrial system? It is not beyond the limits of probability that an inhabitant of Jupiter may be able to perceive and to trace all the variety of scenery connected with Saturn, and its rings and satellites, and to distinguish the planets that revolve around other suns, as distinctly as we perceive with a telescope the satellites with which that planet is attended. We have experimental proof that the inventions of art can extend the range of human vision. The rings of Saturn, the motions of its satellites, the changes which happen in the belts of Jupiter—which no unassisted eye could ever have discerned,—and millions of stars a thousand times more distant than the limits of natural vision, have been brought to view by the invention of the telescope; which shows that the extent of human vision is susceptible of an indefinite increase. And if man can thus improve his natural vision, we need not doubt that the Deity has infinite resources at his command, and that when he

pleases, he can construct visual organs of such vast and extensive powers as far surpass the limits of our comprehension; and it is not improbable, from the variety already known to exist, that such organs are actually to be found throughout different regions of the universe. Our extent of vision by the telescope is found to depend on the extent of area contained in the object-glass, or speculum of that instrument, which enables the eye to take in a greater portion of rays from distant objects than it can do in its natural state; and therefore, if our eyes were formed with pupils of a large dimension, and with a corresponding degree of nervous sensibility in the retina, we might be enabled to penetrate into space to an extent of which we have no conception. Such modifications of vision, and thousands of others, are obviously within the power of Him who at first organized all the tribes of animated existence.

It is highly probable that it is one great design of the Creator to exhibit to all intelligent beings throughout creation a visible display of his glory through the medium of their visual organs; for where no organs of vision exist, the wonderful apparatus for the production and distribution of light so conspicuous throughout the universe, exists in vain; and therefore, if it be allowed to reason from the means to the end, or from the cause to the effect, we must admit that the universal diffusion of light through infinite space, from an infinite variety of bodies, must be intended to produce vision through the medium of organs similar or analogous to ours; in order that rational beings may enjoy the pleasures arising from this sense, and be enabled to appreciate the wonders of the universe, and the perfections of its Creator. The variety of means and contrivances for the diffusion of *light* throughout creation is therefore a demonstrative evidence both of the *existence* of intelligent beings in other worlds, and that they are furnished with visual organs for the purpose of contemplating the objects which it renders visible.

4. The inhabitants of other worlds are invested with *locomotive powers*. This we may infer from the amplitude of space which every world contains, and from the consideration that they are social beings, and hold a regular intercourse with each other. We must, indeed, necessarily suppose that there are no rational beings confined to one spot or point of space, as a tree, a shrub, or any other vegetable; for if this were the case, there could be no improvement either in knowledge or in moral action, the capacity of the intellect could never be expanded, the variety of beauties and sublimities which distinguish all the works of God could never be properly contemplated, most of the pleasures peculiar to an intelligent being could never be enjoyed, and the manifold delights which flow from social intercourse and the contemplation of diversified scenes and objects could never be experienced. The supposition of an incapacity for local motion is therefore inconsistent with the idea of a rational being, and almost involves an absurdity. We find, moreover, that in many of the planets, particularly in Jupiter and Saturn, there is the most ample space provided for exercising the powers of locomotion; these two planets containing more than 220 times the area of the earth's surface, which affords a vast field for excursion, and for observation to their inhabitants. These locomotive powers may be very different from those of man, both in their fleetness and in their mode of operation. We have reason to believe that in many instances they will far exceed ours in swiftness, and in the ease with which they may be performed; for if birds and flying insects, and even certain quadrupeds, are endowed with powers of motion far more swift and energetic than those of man, it is highly probable that rational and social beings, in more expansive worlds than ours, are capable of traversing space with much more ease and agility than the human inhabitants of our globe, otherwise they could not be supposed for ages to accomplish a survey of the world in which they dwell, or to become acquainted with its leading features. Whether such motions, however, are performed on a principle analogous to that on which the wings of birds are constructed, or on any other principle to us unknown, is beyond our province to determine.

5. We may also infer that the inhabitants of other worlds are furnished with a sense corresponding to *the organ of hearing*, and *a faculty of emitting articulate sounds*. Without such a sense and faculty, it is scarcely possible to conceive that social intercourse, and a mutual interchange of sentiment and feeling could be carried on to any extent, or with any great degree of pleasure or improvement, among organized beings. Pure spirits may have modes of intercourse and of communicating thought peculiar to themselves, of which we can at present form no distinct conception; but organized intelligences must necessarily have some *material* mediums, or faculties, by which sentiments and emotions may be expressed and communicated. Some of the planets are found to be environed with atmospheres; and as air is the medium of sound in our terrestrial region, it doubtless serves a similar purpose in other worlds; and consequently we may conclude that the animated beings they contain are furnished with organs for the perception of sounds in all their

modulations. In the representations given in the sacred records of the exercises of superior beings, they are exhibited as uttering articulate sounds, and joining in the harmonies of music. When a multitude of angels descended on the plains of Bethlehem to announce the birth of Messiah to the shepherds, they uttered articulate sounds, and joined in musical strains which struck the ears of the shepherds, and conveyed a distinct impression of the meaning of the sentiments communicated; which circumstance leads us to conclude, that superior intelligences in other regions express sentiments and emotions in a manner somewhat similar to that in which we hold intercourse with one another, by the faculties of speech and hearing.

6. It might, perhaps, be inferred from the *rotation* of the planets—which produces the alternations of light and darkness—that their inhabitants are subject to something analogous to *sleep*, or stated intervals of repose. This may probably be the case in some of the planets, such as Mars or Mercury, which are unaccompanied with satellites; but we know too little of the peculiar circumstances of other worlds to warrant us to speak decisively on this point, as the bodies of the inhabitants of other planets may be so constructed as not to stand in need of being daily invigorated by repose as the bodies of men. Besides, the celestial scenery of some of the planets is so grand, diversified, and picturesque, that a considerable part of their studies and social pleasures may be prosecuted and enjoyed amidst the solemn grandeur and beautiful diversity of their nocturnal scenes, and their contemplations directed to the interesting objects then presented to their view. This is probably the case in the regions of Jupiter and Uranus,—particularly in Saturn, where seven moons may occasionally be beheld in the nocturnal heavens, all exhibiting different *phases*,—some of them changing their apparent phases, magnitude, and motion with great rapidity; some of them entering into an eclipse; and others emerging from it; while two stupendous rings stretch across the concave of the sky, presenting every moment different objects on their surface in the course of their rapid diurnal revolution. Such scenes will, perhaps, be more interesting to the inhabitants of this planet than all the splendours of their noonday;* for all the objects on the surface of this planet, and likewise those on Jupiter and Uranus, will present a different aspect from what they do in the daytime. Being illuminated by the light reflected from a retinue of moons, and by the still more effulgent splendour emitted from the spacious rings, every object will appear enlightened and distinctly visible, a diversity of colouring will be exhibited by the diversity of reflected rays proceeding from the different moons and rings, and the shadows of objects will be increased and blended together, and thrown in different directions, according to the number and relative positions of the nocturnal luminaries which may happen to be above their horizon. On which account, I should be disposed to conclude that the inhabitants of such planets have their physical constitutions organized in such a manner by Divine Wisdom as to fit them for perpetual activity, without standing in need of any repose similar to that of sleep.

The above cursory remarks respecting the physical state of the planetary inhabitants have been deduced chiefly from the ascertained circumstances and phenomena of the planets, and from the general constitution and economy of the universe. Several other conclusions might likewise have been deduced, but I do not intend to enter into the regions of mere conjecture. As rational and intelligent beings, the inhabitants of other worlds must necessarily be considered as prosecuting the study of useful science in reference to all those departments of nature which lie open to their inspection, and that they exercise their mental faculties in such pursuits and investigations. If this be admitted, then we must necessarily conclude that they use all the requisite means for the investigation of truth, and for progressing in knowledge. If, for example, they engage in the study of astronomy (as we have reason to believe the inhabitants of all worlds do) they must make observations, both general and particular; and in order to do so with accuracy and precision, instruments of various descriptions are requisite, and the management of these requires the use of *hands*, or some bodily parts answering a similar purpose; for none of the lower animals on our globe that are deficient in such a member could perform the operations of art which man can perform by the use of his hands. If a horse or a bear were furnished with the same intellectual faculties as the human race, and still retain its present organization, it could make little or no progress either in science or art, without members corresponding to human hands; and therefore we may confidently conclude that members similar or analogous to these are common to us and to the planetary inhabitants. The study of astronomy likewise supposes an acquaintance with *geometry*. The truths of geometry must be the same in every region of the universe, and perhaps of equal

* For a particular description of these scenes, the reader is referred to "Celestial Scenery," chap. viii.

utility to the inhabitants of the most distant worlds as to man on earth. They are truths which are eternal and unchangeable, and which no locality or circumstances within the limits of creation can possibly alter or modify; and therefore must be recognized, in a greater or less degree, by every rational being. The Creator himself has laid the foundation of this science, for he presents us in his works with geometrical figures of various descriptions,—with circles, squares, parallelograms, hexagons and polygons—with ellipses, spheres, spheroids, and other figures, and proposes them, as it were, to our study and contemplation. With geometry, *arithmetic* and other sciences are intimately connected, so that the study of the one supposes that of the other. In short, truth, and every branch of knowledge by which the mind of a rational being can be adorned, must be *substantially* the same in every world throughout the amplitudes of creation.

Some persons, however, may be disposed to object, that the inhabitants of other worlds may see all truths *intuitively*, and that they may have no need to use any means, as we are obliged to do, to acquire and to make progress in knowledge, and that they acquire all their knowledge at once without any exertions,—opinions which have been frequently broached by divines, in reference to the happiness of the future world. But there appears no foundation for such opinions. We have reason to believe that every intellectual being throughout creation *exerts* its powers for the acquisition of truth, and that its advancement in knowledge is *progressive;* for its faculties were bestowed for the very purpose that they might be exerted on all the different objects and manifestations of the Divinity within its reach; and if all knowledge were intuitive and required no exertion of the mental faculty, the individual would be reduced to something like a mere machine, and would be deprived of the pleasures which arise from mental research and investigation. There must likewise be a *progress* in knowledge, arising from the consideration of the immensity of the Divine Being, and of his works, and of the limited nature of finite intelligences. No finite being can ever grasp the incomprehensible Divinity, or the immensity and variety of his operations throughout boundless space; but it may always be *advancing* to a more comprehensive view of the perfections and the empire of the Eternal, and may thus go on from one degree of knowledge to another, gradually approximating *towards* perfection during all the periods of an immortal existence, but will never reach it; and its happiness is connected with this circumstance, that it will never reach perfection, or obtain a *full discovery* of all the glories of the Divinity. But this gradual progression and expansion of intellectual views will be a perennial source of felicity to all virtuous intelligences. Whereas, were the whole of their knowledge acquired at once, or after a short period of duration, the mind would flag, mental activity would cease, the prospect of future knowledge and enjoyment would be cut off, and misery to a certain extent would take possession of the soul.

In fine, although there are, doubtless, marked differences between the planetary inhabitants and the inhabitants of our globe, and although the natural scenery of those worlds may be considerably different from ours, yet it is not improbable, were we transported to those abodes, that we should feel more at home in their society and arrangements than we are now apt to imagine, provided we were once made acquainted with their language, or mode of communicating their ideas. For there are certain relations, sentiments, dispositions, and virtues, which must be common to intellectual and moral beings, wherever existing throughout the material universe. In respect to bodily stature and appearance, we might be apt to suspect that there would be many striking differences in the aspect of the inhabitants of another planet, and that strange and novel forms of corporeal organization would every where be presented to view; yet it is just as probable that in such a world we should contemplate beings not much unlike ourselves, and animated by similar or analogous views, sentiments, and feelings, though placed in circumstances and surrounded with a scenery very different from those of our sublunary region.

Whether we may ever enjoy an intimate correspondence with beings belonging to other worlds, is a question which will frequently obtrude itself on a contemplative mind. It is evident that, in our present state, all direct intercourse with other worlds is impossible. The law of gravitation, which unites all the worlds in the universe in one grand system, separates man from his kindred spirits in other planets, and interposes an impassable barrier to his excursions to distant regions, and to his correspondence with other orders of intellectual beings. But in the present state he is only in the *infancy of his being;* he is destined to a future and eternal state of existence, where the range of his faculties and his connexions with other beings will be indefinitely expanded. "A wide and boundless prospect lies before him," and during the revolutions of an interminable duration, he will, doubtless, be brought into contact and corres-

pondence with numerous orders of kindred beings, with whom he may be permitted to associate on terms of equality and of endearing friendship. All the virtuous intelligences throughout creation may be considered as members of one *great family*, under the peculiar care and protection of the UNIVERSAL PARENT; and it is not improbable, that it is one grand design of the Deity to promote a regular and progressive intercourse among the several branches of his intelligent offspring, though at distant intervals and in divers manners, and after the lapse of long periods of duration.

Such an intercourse may be necessary, in order to the full expansion of the moral and intellectual faculties, and to the acquisition of all that knowledge which relates to the attributes of the Divinity, and the physical and moral government of the universe. For this purpose it may be necessary that branches of the universal family that have existed in different periods of duration, and in regions widely separated from each other, should be brought into mutual association, that they may communicate to each other the results of their knowledge and experience, the diversity of physical and moral circumstances in which they have been placed, and the different arrangements of God's moral government to which they have been respectively subjected. Such views correspond with the representations given in Scripture in reference to the heavenly state. The spirits of "just men made perfect" are represented as joining the society of "an innumerable company of angels," which are only another order of rational beings; and in the visions of celestial bliss, recorded in the book of Revelation, both men and the angelic hosts are exhibited as forming one society, and joining in unison in celebrating the perfections of Him who sitteth on the throne of the universe.

But should the laws of the physical system, and the immense distances which intervene between the several worlds, prevent such associations as I have now supposed, there may be another economy, superior to the physical, which may consist with the most extensive and intimate intercourse of all rational and virtuous beings. There may be a *spiritual* economy established in the universe, of which the physical structure of creation is the basis or platform, or the introductory scene in which rational beings are trained and prepared for being members of the higher order of this celestial or intellectual economy. It appears highly probable that the first introduction of every rational creature into existence is on the scene of a *physical* economy. The diversified scenes and relations of the material world appear to be necessary, in the infancy of being, to form a substratum for thought, or to afford scope for the exercise of the moral and intellectual powers, or materials on which these powers may operate, and likewise for exhibiting a *sensible* display of the character and perfections of the Almighty. The knowledge which may thus be acquired of the scenes and relations of the universe, and the attributes and moral government of its Omnipotent Author, in the course of myriads of ages, must be great and extensive beyond what we can well conceive. This knowledge and experience of physical objects and relations may prepare the rational soul for entering on the confines of a higher and nobler economy, where *immaterial* scenes and relations, and particularly the attributes of Divinity, abstractly considered, may form the chief objects of research and contemplation. Under such a state of economy, we may conceive that intellectual beings, to whatever portion of the material universe they originally belonged, may hold the most intimate converse with one another, by modes peculiar to that economy, and which are beyond the conceptions of the inhabitants of the physical universe; so that distance in point of space shall form no insuperable barrier to the mutual communication of sentiments and emotions.

On grounds similar to those now stated, we might conceive it as not altogether improbable, that the spiritual principle which animates the lower orders of animated nature, and which in some cases bears a near resemblance to the reason of man, may be susceptible of indefinite expansion and improvement by being connected with a superior organization, and that such beings may ultimately pass through various gradations of rank in the physical and intellectual economy, till they arrive at a station superior to that of the most enlightened and improved human beings. But as we are now bordering on the regions of doubt and uncertainty, suffice it to say, that it appears highly probable, from a consideration of the Divine benevolence, of the relations which subsist throughout the physical and intelligent system, and of the intimations contained in the records of revelation, that virtuous and holy intelligences, from different regions of the material creation, as brethren of the same great family, shall, at one period or another, hold the most intimate converse and communion, and rehearse to each other their mutual history and experience. Such intercourse would evidently enhance that felicity which it is the great design of the Creator to communicate, and the means by which it may be effected are obviously within the limits of infinite Wisdom and Omnipotence.

### *On the Moral State of the Inhabitants of other Worlds.*

The moral state of intellectual beings in other worlds is a subject of still greater interest and importance than their physical state and constitution, and the scenes of nature with which they are surrounded; for on the moral temperament of such beings, and the passions and affections they display, will chiefly depend the happiness of the intelligent system throughout every region of the universe. It is possible to suppose a region of creation furnished with every thing that is grand, beautiful and magnificent, and calculated to gratify in the highest degree the senses and imagination, and yet the abode of wretchedness and misery. If passions and dispositions similar to those which actuate the most vicious and depraved class of mankind were universally to prevail in any world, however beautiful and sublime its physical arrangements, true happiness would be banished from its society, and misery, in all its diversified ramifications, would be found pervading its abodes. Even the tempers and dispositions which are frequently exhibited in polished society, and by some men who call themselves Christians and philosophers,—jealousy, emulation, envy, pride, revenge, selfishness, and such like,—were they to reign uncontrolled in any region, would soon transform intellectual beings into an assemblage of fiends, and banish true enjoyment from every department of the social system.

If these sentiments be admitted, it will follow, that were we permitted to range through any of the planetary worlds, the pleasures and enjoyments of such an excursion would chiefly depend on the character and dispositions of those who accompanied us, and of the inhabitants of the planet through which we roamed. Were we to be treated by the inhabitants of another world in the same way as Mr. Park was treated by the Moors when he was traversing the wilds of Africa, or as a poor wretched foreigner is sometimes treated in our own country, we should find little enjoyment amidst all the beauties and novelties of scenery which might meet our eye in such a world, for upon the affections and conduct of intelligent beings towards one another must depend the happiness of individuals, and of the whole social system throughout every department of creation.

It is probable that the greater part of the inhabitants of all worlds are in a state of innocence, or, in other words, that they remain in that state of moral rectitude in which they were created; for we may assume it as an axiom that every rational being, when first ushered into existence, is placed in a state of innocence or moral rectitude, without any natural bias to moral evil. To suppose the contrary would be to admit that the Divine Being, who is possessed of perfect holiness and rectitude, infuses into rational beings at their creation a principle of sin, or a tendency to moral evil, which would be inconsistent with every scriptural view we can take of the character of God. Such beings, therefore, so long as they continue in their primeval rectitude, are in a state of happiness; and every arrangement of the Creator in relation to them must be conceived as having a direct tendency to promote their sensitive and intellectual enjoyment. Moral evil, however, has been introduced into the universe, and we know by experience many of its malignant and miserable effects. For any thing we know to the contrary, the operation of this principle *may be felt* in some other worlds besides our own, though we have reason to believe, from a consideration of Divine goodness, that its effects are not very extensive. Its introduction into the world has doubtless been permitted in order to bring about a greater good to the universe at large than could have been accomplished without it, in order to exhibit to the intelligent system a display of the miserable and extensive effects which necessarily flow from a violation of the original moral laws given forth by the Creator, and to demonstrate the indispensable necessity of a universal adherence to these laws, in order to secure the harmony and the happiness of the intelligent universe.

In conformity to the axiom stated above, we must necessarily suppose that rational beings, wherever existing, were created in perfect moral purity, and had a law or laws impressed upon their minds congenial to the holiness of the Almighty Creator, and calculated to promote the moral order of the intelligent system, and consequently the happiness of every individual belonging to it. *Moral order* consists in the harmonious arrangement, disposition, and conduct of intelligent beings, corresponding to the relations in which they stand to one another and to their Creator, and calculated to promote their mutual happiness. Wherever moral order prevails, every being holds its proper station in the universe, acts according to the nature of that station, uses its faculties for the purpose for which they were originally intended, displays dispositions and emotions towards fellow-creatures and the Creator corresponding to the respective relations in which they stand, and endeavours to promote enjoyment among all surrounding beings.* For the

* For a particular illustration of *moral order*, the reader is referred to "The Philosophy of Religion," *Preliminary Definitions*, sect. I.

purpose of securing moral order, certain moral laws must be supposed to be promulgated by the Creator, or at least written upon the hearts of all rational beings, as principles of action, to regulate all the movements of the intelligent system. These laws must be *substantially* the same as to their general bearings throughout all the worlds in the universe.

But, it may be asked, what are those general laws to which I allude, and have they ever been promulgated to man upon earth? I answer, they have actually been revealed to the inhabitants of our globe by the highest authority, and reason can demonstrate their applicability to all worlds. They are these—"THOU SHALT LOVE THE LORD THY GOD WITH ALL THY HEART, AND WITH ALL THY MIND, AND WITH ALL THY STRENGTH. This is the first and great commandment. And the second is like unto it: THOU SHALT LOVE THY NEIGHBOUR AS THYSELF." These laws are not to be considered as confined merely to the regulation of the affections and actions of human beings, but to every individual of the moral system, wherever existing; for we cannot for a moment suppose that laws directly opposite to these would be given by the Creator to any class of intelligences. It would be inconsistent with every thing we know of the character of the Divinity to imagine that he would promulgate to any class of beings such laws as these:—"Thou shalt hate thy Creator," and "thou shalt hate all thy fellow-creatures." And if such an idea would evidently involve in it a glaring inconsistency and absurdity, then it follows that the very opposite of such injunctions must be the general principles which govern the inhabitants of all worlds that have retained their allegiance to their Creator. There is not a single being possessed of a rational nature, either in the planetary system to which we belong or to any other system throughout the sidereal heavens, but is under indispensable obligations to regulate its conduct by the two general laws or principles to which we have referred, and to yield a complete and unreserved obedience to all that is included in such requisitions. Wherever such obedience is complete, order, harmony, and happiness are the natural and necessary results; but could we suppose these laws reversed, and the inhabitants of any worlds to act on principles directly opposite, a scene of anarchy, confusion, and misery would ensue, which would completely disorganize the social system, and render existence a curse rather than a blessing; and in worlds where those laws are *partially* violated, as in the world in which we dwell, disorder and misery will be the result in proportion to the frequency and extent of their violation.

These are the laws by which not only man on earth, but all "the principalities and powers of heaven," are governed and directed, and by which they are bound to regulate all their thoughts, affections, and conduct. The lowest orders of rational existence come within the range of these universal laws, and the highest orders of the seraphim are not beyond their control. As the law of gravitation extends its influence throughout all the planetary worlds, and even to the remotest stars, uniting the whole in one harmonious system, so the law of universal *love* diffuses its influence over the intelligent universe, uniting the individuals who are subject to its sway in one harmonious and happy association. Hence it follows, that were we completely animated by this noble principle, and were we permitted to visit those worlds where it reigns supreme, and to mingle with their inhabitants, we should be recognized as friends and brethren, and participate of all those pleasures and enjoyments of which it is the source. The full recognition, then, of the laws to which we have referred, and their complete and uninterrupted influence over the moral powers, may be considered as qualifying the individual for being a citizen of the great moral universe, and for associating with all holy beings throughout the wide empire of omnipotence, should he ever be permitted, at any period of duration, to visit other worlds, and mingle with other orders of rational intelligences.*

These laws, in reference to the inhabitants of our world, diverge into numerous ramifications. The precepts of the moral law, or the ten commandments, are so many branches of moral duty flowing from these first principles; and in the discourses of our Saviour and the practical parts of the apostolic epistles they diverge into still more specific and minute ramifications, bearing upon all the diversified relations of life and the various circumstances connected with moral conduct. But all the particular rules and precepts alluded to are resolvable into the general principles or affections stated above, and bear the same relations to each other as the trunk of a tree to its branches, or as a fountain to the diversified streams which it sends forth. In other worlds relations may exist different from those which are found in human society, and consequently particular precepts different from ours may form a part of their moral code, while certain relations which obtain among us may have no place among other orders of beings, and of course, the precepts which particularly bear upon such relations will be in their cir-

* For more particular details on this subject, the reader is referred to "The Philosophy of Religion," particularly chap. ii. sect. vi.

cumstances altogether unnecessary. But we may rest assured that all the particular precepts, applicable to whatever circumstances and relations may exist in other regions of creation, will be founded on the universal principles to which we have adverted, and be completely conformable to their spirit, and to the benevolent designs they are intended to accomplish.

In all those worlds where the love of God and of fellow-intelligences reigns supreme, the inhabitants may be conceived to make rapid improvements in knowledge; for the malignant principles and passions which prevail among men have, in numerous instances, been the means of retarding the progress of useful science and its diffusion throughout society. But where love in all its emanations pervades every mind, society will unite and harmonize in the prosecution of every plan by which the intellectual faculty may be irradiated and happiness diffused. Besides, in such a state of society, truth will be for ever triumphant and falsehood unknown. Every fact will be fairly and truly exhibited without deception or the least tendency to misrepresentation or exaggeration. There will be the most complete reliance on personal evidence in regard to every fact and circumstance which has been witnessed by any individuals; for want of which confidence in our world, the rational inquirer has been perplexed by the jarring statements of lying travellers and pretended philosophers; erroneous theories have been framed, the mists of falsehood have intercepted the light of truth, the foundations of true knowledge undermined, and science arrested in its progress towards perfection. All such evils, however, will be unknown in worlds where the inhabitants have arrived at moral perfection.

In fine, from what has been now stated, we may conclude that the *spirit*, the *principle*, and *essence* of our holy religion, as delineated in the Scriptures, must be common to all the inhabitants of the universe who have retained their primeval rectitude and innocence.

## CHAPTER XIX.

### *A Summary View of the Universe.*

Having in the preceding pages afforded a few sketches in reference to the principal facts connected with the sidereal heavens, which constitute the most extensive portion of creation within the limits of our knowledge, it may not be inexpedient to take a summary view of the range of objects to which our attention has been directed, in order to direct our occasional reflections on this subject, and to enable us to form an approximate, though faint and limited, idea of that universe over which Omnipotence presides, and of the perfections of its adorable Author.

We can obtain an approximate idea of the universe only by commencing a train of thought at those objects with which we are more immediately conversant, and ascending gradually to objects and scenes more distant and expansive. We are partly acquainted with the objects which constitute the landscape around us, of which we form a part,—the hills, the plains, the lofty mountains, the forests, the rivers, the lakes, and the portions of the ocean that lie immediately adjacent. But all the range of objects we can behold in an ordinary landscape forms but a very small and inconsiderable speck, compared with the whole of the mighty continents and islands, the vast ranges of lofty mountains, and the expansive lakes, seas, and oceans which constitute the surface of the terraqueous globe. It would be requisite that more than *nine hundred thousand landscapes*, of the extent we generally behold around us, should be made to pass in review before, and a sufficient time allowed to take a distinct view of the objects of which they are composed, ere we could form an adequate conception of the magnitude and the immense variety of objects on the whole earth. Were only twenty minutes allotted for the contemplation of every landscape, and ten hours every day, it would require ninety years of constant observation before all the prominent objects on the surface of the globe could thus be surveyed. Were it possible to take a distinct mental survey of such a number of landscapes, we might acquire a tolerable conception of the amplitude of our globe, and it would serve as a standard of comparison for other globes which far excel it in magnitude. But I believe very few persons are capable of forming, *at one conception*, a full and comprehensive idea of the superficial extent of the world in which we dwell, whose surface contains no less than one hundred and ninety-seven millions of square miles. The most complete conception we can form must indeed fall very far short of the reality.

But however ample and correct our conceptions might be, and however great this earth might appear in the view of the frail

beings that inhabit it, we know that it is only an inconsiderable ball, when compared with some of the planetary bodies belonging to our own system. One of these bodies would contain within its dimensions nine hundred globes as large as this earth,—another, fourteen hundred of similar globes; and were five hundred globes, as large as that on which we dwell, arranged on a vast plane, the outermost ring of the planet Saturn, which is 643,000 miles in circumference, would inclose them all. Such are the vast dimensions of some of those bodies, which appear only like lucid specks on the concave surface of our sky. This earth, however, and all the huge planets, satellites, and comets, comprised within the range of the solar system, bear a very small proportion to that splendid luminary which enlightens our day. The SUN is five hundred times larger than the whole, and would contain within its vast circumference thirteen hundred thousand globes as large as our world, and more than sixty millions of globes of the size of the moon. To contemplate all the variety of scenery on the surface of this luminary, would require more than fifty-five thousand years, although a landscape of five thousand square miles in extent were to pass before our eyes every hour. Of a globe of such dimensions, the most vigorous imagination, after its boldest and most extensive excursions, can form no adequate conception. It appears a kind of universe in itself; and ten thousands of years would be requisite before human beings, with their present faculties, could thoroughly investigate and explore its vast dimensions and its hidden wonders.

But great as the sun and his surrounding planets are, they dwindle into a point when we wing our flight towards the starry firmament. Before we could arrive at the nearest object in this firmament, we behoved to pass over a space at least twenty billions of miles in extent,—a space which a cannon ball, flying with its utmost velocity, would not pass over in less than four millions of years. Here every eye in a clear winter's night may behold about a thousand shining orbs, most of them emitting their splendours from spaces immeasurably distant; and bodies at such distances must necessary be of immense magnitude. There is reason to believe that the least twinkling star which our eyes can discern is not less than the sun in magnitude and in splendour, and that many of them are even a hundred or a thousand times superior in magnitude to that stupendous luminary. But bodies of such amazing size and splendour cannot be supposed to have been created in vain, or merely to diffuse a useless lustre over the wilds of immensity. Such an idea would be utterly inconsistent with the perfections of the Divinity, and all that we know of his character from the revelations of his word. If this earth would have been "*created* in vain" had it not been inhabited,* so those starry orbs, or, in other words, those magnificent suns would likewise have been created in vain, if retinues of worlds and myriads of intelligent beings were not irradiated and cheered by their benign influence.

These thousand stars, then, which the unassisted eye can perceive in the canopy of heaven, may be considered as connected with at least *fifty thousand worlds;* compared with the amount of whose population all the inhabitants of our globe would appear only as "the smallest dust of the balance." Here the imagination might expatiate for ages of ages in surveying this portion of the Creator's kingdom, and be lost in contemplation and wonder at the vast extent, the magnitude, the magnificence, and the immense variety of scenes, objects, and movements which would meet the view in every direction; for here we have presented to the mental eye, not only single suns and single systems, such as that to which we belong, but suns revolving around suns, and systems around systems,—systems not only double, but treble, quadruple, and multiple, all in complicated but harmonious motion, performing motions more rapid than the swiftest planets in our system, though some of them move a hundred thousand miles every hour,—finishing periods of revolution, some in 30, some in 300, and some in 1600 years. We behold suns of a blue or green lustre revolving around suns of a white or a ruddy colour, and both of them illuminating with contrasted coloured light the same assemblage of worlds. And if the various orders of intelligences connected with these systems were unveiled, what a scene of grandeur, magnificence, variety, diversity of intellect, and of wonder and astonishment, would burst upon the view! Here we might be apt to imagine that the whole glories of the Creator's empire have been disclosed, and that we had now a prospect of universal nature in all its extent and grandeur.

But although we should have surveyed the whole of this magnificent scene, we should still find ourselves standing only on the outskirts, or the extreme verge of creation. What if all the stars which the unassisted eye can discern be only a few scattered orbs on the outskirts of a cluster immensely more numerous? What if all this scene of grandeur be only as a small lucid speck compared with the whole extent of the firmament? There is demonstrative evidence from observation that this is in reality the case. In one lucid circle in the heavens, scarcely perceptible on a

* Isaiah xlv. 18.

cursory view of the firmament, there are twenty thousand times more stars distinguishable by the telescope than what the naked eye can discern throughout the visible canopy of heaven. The Milky Way, were it supposed to contain the same number of stars throughout its whole extent as have been observed in certain portions of it, would comprise no less than 20,191,000 stars; and as each of these stars is doubtless a sun, if we suppose only fifty planets or worlds connected with each, we shall have no less than 1,009,550,000, or more than *a thousand millions* of worlds contained within the space occupied by this lucid zone. Here an idea is presented which completely overpowers the human faculties, and at which the boldest imagination must shrink back at any attempts to form an approximate conception. A thousand millions of worlds! We may state such a fact in numbers or in words, but the brightest and most expansive human intellect must utterly fail in grasping all that is comprehended in this mighty idea; and perhaps intelligences possessed of powers far superior to those of man are inadequate to form even an approximate conception of such a stupendous scene. Yet this scene, magnificent and overpowering as it is to limited minds such as ours, is not the scene of the universe; it is only a comparatively insignificant speck in the map of creation, which beings at remote distances may be unable to detect in the canopy of their sky, or at most will discern it only as an obscure point in the furthest extremities of their view, as we distinguish a faint nebulous star through our best telescopes.

Ascending from the Milky Way to the still remoter regions of space, we perceive several thousands of dim specks of light which powerful telescopes resolve into immense clusters of stars. These *nebulæ*, as they are called, may be considered as so many milky ways, and some of them are supposed even to "outvie our Milky Way in grandeur." Above three thousand of these nebulæ have been discovered; and if only two thousand be supposed to be resolvable into starry groups, and to be as rich in stars at an average as our Milky Way, then we are presented with a scene which comprises 2000 times 20,191,000, or 40,382,000,000, that is, more than *forty thousand millions* of stars. And if we suppose, as formerly, fifty planetary globes to be connected with each, we have exhibited before us a prospect which includes 2,019,100,000,000, or two billions, nineteen thousand one hundred millions of worlds. Of such a *number* of bodies we can form no distinct conception, and much less can we form even a rude or approximate idea of the *grandeur* and *magnificence* which the whole of such a scene must display. Were we to suppose each of these bodies to pass in review before us *every minute*, it would require more than three millions, eight hundred and forty thousand years of unremitting observation before the whole could be contemplated even in this rapid manner. Were an hour's contemplation allotted to each, it would require two hundred and thirty millions, four hundred thousand years till all the series passed under review; and were we to suppose an intelligent being to remain fifty years in each world for the purpose of taking a more minute survey of its peculiar scenery and decorations, 100,955,000,000,000, or a hundred billions, nine hundred and fifty-five thousand millions of years would elapse before such a survey could be completed; a number of years which to limited minds seem to approximate to something like eternity itself.

Still, *all this countless assemblage of suns and worlds is not the universe.* Although we could range on the wings of a seraph through all this confluence of sidereal systems, it is more than probable that we should find ourselves standing only on the verge of creation, and that a boundless prospect, stretching towards infinity on every side, would still be presented to view; for we cannot suppose for a moment that the empire of Omnipotence terminates at the boundaries of human vision, even when assisted by the most powerful instruments. Other intelligences may have powers of vision capable of penetrating into space a hundred times further than ours when assisted with all the improvements of art; but even such beings cannot be supposed to have penetrated to the uttermost boundaries of creation. Man in future ages, by the improvements of optical instruments, may be able to penetrate much further into the remote regions of space than he has hitherto done, and may descry myriads of objects which have hitherto remained invisible in the unexplored regions of immensity. Ever since the invention of the telescope, one discovery has followed another in almost regular succession. In proportion to the increase and activity of astronomical observers, and the improvement of the instruments of observation, the more remote spaces of creation have been explored, and new scenes of the universe laid open to human contemplation. And who shall set boundaries to the improvements and discoveries of future and more enlightened generations? Before the invention of the telescope, it would have been foolish to have asserted that no more stars existed than those which were visible to the naked eye; and after Galileo had discovered with his first telescope hundreds of stars which were previously unknown, it would have been equally absurd to have maintained that the telescope

would never be further improved, and that no additional stars would afterwards be discovered. It would be a position equally untenable to maintain, that we shall never be able to descry objects in the heavens beyond the boundaries which we have hitherto explored, since science has only lately commenced its rapid progress, and since man is little more than just *beginning* to employ his powers in such investigations.

But however extensive may be the discoveries of future ages, we may lay it down as an axiom, that neither man nor any other rank of finite beings will ever be able to penetrate to the further boundaries of the creation. It would be presumptuous to suppose that a being like man,—whose stature is comprehended within the extent of two yards, who vanishes from the sight at the distance of a German mile, whose whole habitation sinks into an invisible point at the distance of Jupiter, who resides on one of the smallest class of bodies in the universe, and whose powers of vision and of intellect are so limited,—should be able to extend his views to the extreme limits of the empire of the Eternal, and to descry all the systems which are dispersed throughout the range of infinitude. It is more reasonable to believe that all that has yet been discovered of the operations of Omnipotence that lie within the boundaries of human vision, is but a very small portion of what actually exists within the limits of creation; that the two billions and nineteen thousand millions of worlds which we have assumed as the scene of the visible universe, are only as a single star to the whole visible firmament, or even as a single grain of sand to all the myriads of particles which cover the sea-shores and the bed of the ocean, when compared with what lies beyond the utmost range of mortal vision; for who can set bounds to infinitude, or to the operations of Him whose power is omnipotent, "whose ways are unsearchable," and "whose understanding is infinite?" All that we have yet discovered of creative existence, vast and magnificent as it appears, may be only a small corner of some mightier scheme which stretches throughout the length and breadth of immensity,—of which the highest created intellect may have only a few faint glimpses, which will be gradually opening to view throughout the revolutions of eternity, and which will never be fully explored during all the periods of an interminable existence. What is seen and known of creation may be as nothing compared with what is unseen and unknown; and as the ages of eternity roll on, the empire of the Almighty may be gradually expanding in its extent, and receiving new additions to its glory and magnificence.

Hence we may conclude that there is no created being, even of the highest order of intelligences, that will ever be able to survey the whole scene of the universe. Of course, man, though destined to immortality, will never acquire a complete knowledge of the whole range of the Creator's operations, even during the endless existence which lies before him; for his faculties, however much expanded in that state, will be utterly inadequate to grasp a scene so boundless and august. It will be a part of his happiness that he will never be able to comprehend the universe; for at every period of his future existence he will still behold a boundless prospect stretched out before him, with new objects continually rising to view, in the contemplation of which, innumerable ages may roll away without the least apprehension of ever arriving at the termination of the scene. Were a superior intelligence ever to arrive at such a point, from that moment his happiness would be diminished, his intellectual powers would lose their energy, his love and adorations of the Supreme would wax faint and languid, and he would feel as if nothing new and transporting were to be added to his enjoyments throughout all the periods of his future existence. But the immensity of the universe, and the boundless nature of the dominions of "the King Eternal," will for ever prevent any such effects from being produced in the case of all virtuous and holy intelligences.

Besides the numerous bodies to which we have above alluded, there are several other objects which require to be contemplated, in order to amplify our views of the visible universe. Those nebulous specks in the remote regions of the heavens termed *planetary neblusæ* have never yet been resolved into stars, and are in all probability bodies of a different nature from the Milky Way and other sidereal systems. Their magnitude is astonishing, since some of them would fill a cubical space equal to the diameter of the orbit of Uranus, which would contain 24,000,000,000,000,000,000,000,000,000, or twenty-four thousand quartillions of solid miles; that is, they are sixty-eight thousand millions of times larger than the sun. Such bodies present to our view *magnitudes* more astonishing than any others to be found within the range of the visible creation, and overwhelm the mind with wonder and amazement at what can possibly be their nature and destination. Several other nebulæ are no less wonderful, such as that in the constellation of Orion which even surpasses in magnitude the dimensions now stated. It has been computed to be 2,200,000,000,000,000,000, or two trillions, two hundred thousand billions of times larger than the sun,—a magnitude

which we can scarcely suppose within the power of any finite being to grasp or to comprehend. For what end such huge masses of matter were created must remain a mystery to mortals so long as they are confined to this sublunary scene. Perhaps they are intended to give us a glimpse of objects and arrangements in the Divine economy altogether different from those we perceive in the planetary system, and in the other parts of the sidereal heavens. But whatever may be their ultimate destination, we may rest assured that they serve a purpose in the plan of the Divine administration worthy of their magnitude, and of the perfections of Him by whom they were created. They were brought into existence by the same power which reared the other parts of creation; and as power is always accompanied with wisdom and goodness, they must have an ultimate reference to the accommodation and happiness of rational beings, under an economy, perhaps widely different from that of the planetary and other systems.

Having taken a cursory view of the magnitudes of the numberless bodies scattered through the regions of space, let us now consider the *motions* which are incessantly going forward in every part of the universe; for all the myriads of globes and systems to which we have alluded are in rapid and perpetual motion; and we have no reason to believe that there is a single quiescent body throughout the immensity of creation. We have here planets revolving around suns, planets revolving around planets, suns performing their revolutions around suns, suns revolving around the centres of sidereal systems, and, in all probability, every system of creation revolving round the centre and *Grand Mover* of the whole. The rate of these motions, in every known instance, is not less than several thousands of miles every hour, and in many instances, thousands of miles in a minute. The motions which are found among the planetary globes appear, at first view, altogether astonishing, and almost to exceed belief, when we consider the enormous size of some of these bodies. That a globe a thousand times larger than our world should fly at the rate of thirty thousand miles an hour, and carry along with it a retinue of other mighty globes in its swift career, is an object that may well strike us with wonder and amazement. But the fixed stars—though to a common observer they appear exactly in the same positions with regard to each other—are found, in some instances, to be carried forward with motions far more rapid than even the bodies of the planetary system, though their magnitude is immensely superior. We have already seen that the star 61 Cygni, whose apparent motion is five seconds annually, and consequently imperceptible to a common observer, yet at the distance at which the star is known to be placed, this motion is equivalent to one thousand five hundred and fifty-two millions of miles in a year; four millions, two hundred and fifty-two thousand miles a day, and one hundred and seventy-seven thousand miles an hour. Other stars are found to move with velocities nearly similar, as $\mu$ Cassiopeia, which moves above three millions of miles a day, which is at the rate of two thousand one hundred and sixty miles every minute. These are motions altogether incomprehensible by human beings, especially when we take into consideration the enormous magnitude of the stars, some of which may be a thousand times larger than all the planets and comets belonging to our system. They display the amazing and uncontrollable ENERGIES OF OMNIPOTENCE, and afford a distinct source of admiration and astonishment in addition to all the other wonders of the universe. If, then, we would endeavour to attain a comprehensive idea of the motions going forward throughout the spaces of immensity, we must not only conceive of planets revolving around luminous centres, but of suns revolving around suns,—of suns and systems revolving around the centres of the nebulæ to which they respectively belong,—of all the systems and nebulæ of the universe revolving in immense circumferences around the throne of the Eternal, the great centre of all worlds and beings,—of each sun, and planet, and system, notwithstanding, pursuing a course of its own in different directions, and in numerous instances acted upon by different forces,—in short, of the ten thousand times ten thousands of luminous and opaque globes, of every rank and order, within the circuit of creation,—all performing their rapid but harmonious motions throughout every region of space, and without intermission, in obedience to the laws of their Creator.

Again, we cannot be supposed to have attained a comprehensive conception of the universe, without taking into account the sensitive and intellectual beings with which it is replenished. We ought never to consider the numerous orbs revolving throughout infinite space as mere masses of rude matter, arranged into systems merely to give a display of Almighty Power, but as means for accomplishing a higher and nobler end,—the diffusion of happiness among countless orders of intelligent existence. And as this idea must necessarily be admitted, what a *countless* multitude of percipient beings must people the amplitudes of creation! On our globe there are supported at least 800 millions of human be

ings; but it is capable of supporting twenty times that number, or sixteen thousand millions, if all its desolate wastes were cultivated and peopled. Besides man, there are numerous orders of other sensitive beings: there are at least 500 species of quadrupeds, 4000 species of birds, 3000 species of fish, 700 species of reptiles, 50,000 species of insects besides thousands which the microscope alone can enable us to perceive—at least sixty thousand species in all. If every species contain about 500 millions of individuals, then there will be no less than 30,000,000,000,000, or thirty billions of individuals belonging to all the different classes of sensitive existence on the surface of our globe.

If this earth, then, which ranks among the smaller globes of our system, contain such an immense number of living beings, what must be the number of sentient and intellectual existence in all the worlds to which we have alluded! We assumed, on certain data, that 2,019,1000,000,000, or two billions of worlds, may exist within the bounds of the visible universe; and, although no more beings should exist in each world, at an average, than on our globe, there would be the following number of living inhabitants in these worlds, 60,573,000,000,000,000,000,000,000; that is, sixty quartillions, five hundred and seventy-three thousand trillions, a number which transcends human conception. Among such a number of beings, what a variety of orders may exist, from the archangel and the seraph to the worm and the microscopic animalculum! What a diversity of ranks in the intellectual scale, from the point of the human faculties to the highest order of created beings, may be found throughout this immensity of existence! Some, perhaps, invested with faculties as far surpassing those of man as man surpasses in intellectual energy the worms of the dust, and still approximating nearer and nearer to the Deity. What a variety may exist among them in the form, organization, senses, and the movements of their corporeal vehicles! What a wonderful and interesting scene would their history disclose, were the whole series of events in the Divine administration towards them laid open to our view!—the different periods in duration at which they were brought into existence; the special laws of social and moral order peculiar to each class of intelligences; the modes of improving the intellect, and the progress they have made in universal knowledge; the scenes of glory or of terror through which any particular classes of beings might have passed; the changes and revolutions that may await them; and the final destination to which they are appointed. These and numerous other circumstances connected with the moral and intellectual universe open to view a source of knowledge, and a subject of sublime investigation, which superior intellects might prosecute without intermission, with increasing admiration and rapture, and never arrive at the termination of their pursuits during all the periods of an endless existence.

Such is a summary view of the universe, in so far as its scenes lie open to our knowledge and investigation. The idea it presents is altogether overpowering to the human faculties, but it is nothing else than what we should naturally expect, when we consider that the Being who formed it is self-existent and eternal; possessed of infinite wisdom, almighty power, and boundless goodness; and fills the infinity of space with his presence. It is like himself, boundless, and incomprehensible by finite minds; but exhibits to every order of intelligent beings a *sensible display* of "His Eternal Power and Godhead." Without the existence of such a universe, the infinite attributes of the Almighty could not be fully recognized and appreciated by his intelligent offspring. But here we behold, as in a mirror, the invisible perfections of the Divinity, "whom no man hath seen or can see," adumbrated, as it were, and rendered visible, in every part of creation, to the eyes of unnumbered intelligences; for there is no point of space in which a rational being could be placed, in which he would not find himself surrounded with sensible evidences and displays of the operations of an all-wise, an all-powerful, and incomprehensible Deity. "He has not left himself without a witness" to his existence, and his incessant energies, in any parts of his dominions, or to any order of his creatures, wherever existing. "If we should ascend to heaven, he is there." If we should descend to the lower regions, he is there also to be seen in his operations.—"If we take the wings of the morning," and fly along with the sun from east to west, and continue our course without intermission through regions of space invisible to mortal eye, "even there his hand would lead us, and his right hand uphold us." "Darkness," unfolds the grandeur of his operations and the glories of his nature, as well as the "light" of the orb of day. Though, on the wings of a seraph we could fly in every direction through boundless space, we should every where find ourselves encompassed with his immensity, and with the manifestations of his presence and agency. Of such a Being, and of the universe he has formed, we may exclaim in the language of an inspired writer—"O the depth of the riches both of the wisdom and of the knowledge of God! How unsearchable are his operations, and his ways past finding out!"

Of this universe we can only form an approximate idea by comparing one small por

Angellic imperialist



sion of it with another, and by allowing the mind to dwell for a considerable time on every scene we contemplate. We must first endeavour to acquire a comprehensive conception of the magnitude of the globe on which we dwell, and the numerous diversity of objects it contains; we must next stretch our view to some of the planetary globes, which are a thousand times greater in magnitude; and to such an orb as the sun, which fills a space thirteen hundred thousand times more expansive. Ranging through the whole of the planetary system, we must fix our attention on every particular scene and object, imagine ourselves traversing the hills, and plains, and immense regions of Jupiter, and surveying the expansive rings of Saturn in all their vast dimensions and rapid motions, till we have obtained the most ample idea which the mind can possibly grasp of the extent and grandeur of the planetary system. Leaving this vast system, and proceeding through boundless space till all its planets have entirely disappeared, and its sun has dwindled to the size of a small twinkling star, we must next survey the thousand stars that deck the visible firmament, every one of which must be considered as a SUN, accompanied with a system of planets no less spacious and august than ours. Continuing our course through depths of space immeasurable by human art, we must penetrate into the centre of the Milky Way, where we are surrounded by suns, not only in thousands, but in *millions*. Here the imagination must be left for a length of time, to expatiate in this amazing and magnificent scene, and try if it can form any faint idea of twenty millions of suns, surrounded with a thousand millions of planets. Suppose one of these bodies to pass before the eye or the imagination every minute, it would require 1900 years before the whole could pass in review, and each produce a distinct impression as a separate object.

In a scene like this, the boldest imagination is overpowered and bewildered, amidst number and magnitude, and feels utterly incompetent to grasp the ten thousandth part of the overwhelming idea presented before it. Winging our flight from the Milky Way, over unknown and immeasurable regions, regions where infinitude appears opening upon us in awful grandeur, we approach some of those immense starry clusters called NEBULÆ, every one of which may be considered as another milky way, with its ten thousands and millions of suns. Here the imagination must make a solemn pause, and take a wider stretch, and summon up all its powers, and force, and vigour; for here we have not merely *one* milky way, with its millions of stars, to contemplate, but *thousands*. If the immense splendour and amplitude of one milky way overwhelms us with amazement, and with an emotion almost approaching to terror, what an overpowering effect should two thousand of such scenes, which have already been discovered, produce upon minds so feeble and limited as ours! Such a scene not only displays to us, beyond every other, the incomprehensible *energies of Omnipotence*, but seems to intimate that there are created beings existing in the universe, endowed with powers of intelligence capable of forming a much more approximate idea of such objects than beings such as man, who may be considered as standing near the lowest point of the scale of intellectual existence. These "thrones and dominions, principalities and powers of Heaven," may be able to form a comprehensive conception of such a scene as the Milky Way, which baffles the utmost efforts of the human faculties.

Soaring beyond all these objects, we behold, as it were, a new universe in the immense magnitude of the planetary and other nebulæ, where separate stars have never been perceived; and besides all these, there may be thousands and ten thousands, and millions of opaque globes of prodigious size, existing throughout every region of the universe, and even in that portion of it which is within the limits of our inspection, the faintness of whose light prevents it from ever reaching our eyes. But, far beyond all such objects as those we have been contemplating, a boundless region exists, of which no human eye has yet caught a glimpse, and which no finite intelligence has ever explored. What scenes of power, of goodness, of grandeur, and magnificence, may be displayed within this unapproachable and infinite expanse, neither men nor angels can describe, nor form the most rude conception. But we may rest assured that it is not an empty void; but displays the attributes of the Deity in a manner no less admirable and glorious, and perhaps much more so, than all the scenes of creation within the range of our vision. Here, undoubtedly, is that splendid region so frequently alluded to in the Scriptures, designated by the emphatic name, "THE HEAVEN OF HEAVENS," evidently importing that it is the most glorious and magnificent department of creation. Countless myriads of beings, standing at the highest point of the scale of intellect, and invested with faculties of which we have no conception, must inhabit those regions; for we are positively informed that "hosts of intelligent beings reside in such abodes, and that "these hosts of the heaven of heavens worship God." But here our contemplations must terminate. Here imagination must drop its wing, since it can penetrate no further into the dominions

of Him who sits on the throne of immensity. Overwhelmed with a view of the magnificence of the universe, and of the perfections of its Almighty Author, we can only fall prostrate in deep humility and adoration, and exclaim, "Great and marvellous are thy works, Lord God Almighty! Thou art worthy to receive glory, and honour, and power; for thou hast created all worlds, and for thy pleasure they are and were created."

I shall conclude this subject with the following remarks:

1. All the vast systems to which we have alluded are the workmanship of an Infinite and Eternal Being, and display the grandeur of his perfections. It is impossible that such an amazing universe, arranged with such exquisite order, and all the bodies it contains moving with such regular and rapid motions, could have formed itself, or been produced by the fortuitous concourse of atoms. The very surmise that such a thing was possible is one of the wildest hallucinations that ever entered the human mind. It is a first principle connected with the constitution of every intellectual nature, and without the admission of which there can be no reasoning, that there is "a connexion between cause and effect," and that "every effect must have a corresponding cause adequate to its production." The universe is an *effect*, the most sublime and glorious which the human mind can contemplate, and the natural and *necessary* conclusion which it almost instinctively draws is, that it is the production of an Eternal, Intelligent, and Almighty Being. This is a conclusion which has been deduced by men of all nations, and in every period of the world. "There is no nation or people," says Cicero, "so barbarous and ignorant as not to acknowledge a powerful and Supreme Divinity."

It is as natural for the human understanding, in its original and unbiassed state, when contemplating the frame of the universe, to infer the existence of a Deity, as it is the property of the eye to distinguish light and colours, and of the ear to distinguish sounds. The principle from which this conclusion is deduced is exactly the same as that by which, from the contemplation of a building, we infer a builder, and from the elegance and utility of every part of the structure, we conclude that he was a wise and skilful architect; or that by which, from an inspection of a clock or watch, or any other piece of useful machinery, we infer not only the existence, but the qualities and attributes, of the contriver and artificer. The man who is incapable of at once deducing such conclusions ought to be regarded as destitute of the reasoning faculty; and if we thus necessarily infer the cause from the effect in the case of human art, can we for a moment hesitate to ascribe the production of this amazing universe which surrounds us, to a Being of infinite knowledge, wisdom, and power, adequate to bring into existence such an immense and wonderful machine, and to preserve it in harmony, from age to age, amidst all its diversified and complicated movements? That ever a doubt was entertained on this subject is a plain proof that man has lost, in part, that light of reason and intelligence with which he was originally endued, or that he is sometimes urged on by depraved passions and a pride of singularity to utter sentiments which he does not sincerely believe. As Cicero long ago declared—"He who thinks that the admirable order of the celestial orbs, and their constancy and regularity, on which the conservation and good of all things depend, to be void of a mind that governs them, he himself deserves to be accounted void of a mind." It is "the *fool*" alone, in the strictest sense of the word, whatever may be his pretended learning, who dares to declare "there is no God."

And as the universe demonstrates the *existence*, so it displays the *attributes* of the Eternal. The manifestation of himself to numberless orders of intelligent beings must have been the great end intended in bringing the universe into existence. This manifestation is made chiefly in *actions*—in actions which display greatness, wisdom, and goodness, beyond all bounds. His greatness appears from the immensity of *power* which the universe exhibits. The power necessary to move a single planet in its course far transcends human conception. What, then, must be the energy and extent of that power which set in motion and still upholds all the planets, worlds, and systems dispersed throughout the spaces of infinitude! The highest created intelligence must be utterly overwhelmed and confounded when it attempts to contemplate or to grasp an idea of omnipotence. His knowledge, wisdom, and unceasing agency are no less conspicuous in the arrangement and direction of every thing that exists in heaven and on earth. As his presence pervades all space, so his agency is displayed in the minutest movement of every part of the vast whole. This great and incomprehensible Being moves every atom, expands every leaf of the forest, decks every flower, conveys the sap through the ramifications of every tree, conducts every particle of vapour to its appointed place, directs every ray of light from the sun and stars, every breath of wind, every flash of lightning, every movement of the meanest worm, and every motion of the smallest microscopic animalculum; while at the same time he supports the planets in their courses, guides the comet in its eccentric

career, regulates the movements of millions of resplendent systems, and presides in sovereign authority over unnumbered hosts of intelligent existence; directing all the mysterious powers of knowledge, virtue, and moral action to subserve the purposes of his will, and accomplish the ends of his moral government. In every department of this universe, likewise, his *goodness* is displayed to unnumbered orders of beings, sentient and intellectual; for all the powers of intelligence and action possessed by every creature in heaven and on earth, from the archangel to the worm, and all the happiness they now or ever will enjoy, are derived from him as the uncreated source of all felicity.

Under this glorious and stupendous Being we live and move; our comforts and enjoyments, while passing through this transitory scene, are wholly in his hands, and all our prospects of enjoyment beyond the range of our earthly career are dependent on his mercy and favour. His omnipotent arm supports us every moment; every breath we draw, every pulse that beats within us, every muscular power we exert, every sound that strikes our ears, and every ray of light that enters our eye-balls, is dependent on his sovereign will. All that we hope for beyond the limits of time and throughout the revolution of eternity depends upon his power, his wisdom, his benevolence and his promises. Were he to withhold the powers and agencies under which we now live and act, we could neither think nor speak, hear nor see, feel nor move; the whole assemblage of living beings in our world would be changed into immovable statues, and this earth transformed into a barren waste and an eternal solitude. To the service of this glorious Being all the powers and faculties with which he has endowed us ought to be unreservedly consecrated. As his highest glory and blessedness consist in bestowing benefits on his intelligent offspring, so we ought to be imitators of him in his boundless beneficence, by endeavouring to communicate happiness to all around us. "To do good, and to communicate, forget not; for with such sacrifices God is well pleased." To him, as the "Father of our spirits and the former of our bodies," is due the highest degree of our love and gratitude; on him we ought to rely for every blessing, and humbly resign ourselves to his disposal under every event; for "all things are of God," and all are conducted with supreme and unerring wisdom and goodness to an end immortal and divine.

2. The immensity and magnificence of the universe and the attributes of Deity it displays are considerations which ought to be taken into account in all our views of religion. There is a class of men who, in prosecuting scientific pursuits, wish to discard every thing that has a bearing on religion when deduced from the investigations of science, and can scarcely refrain from a sneer, when the arrangements in the economy of nature are traced to the agency of their All-wise and Omnipotent Creator; as if the objects which science professes to investigate had no relation to the views we ought to entertain of the Divinity, and ought never to be traced to their great first cause. On the other hand, there are many professed religionists who, from mistaken notions of piety, would set aside the study of the works of God, as having no connexion whatever with the exercises of piety and the business of religion, and as even injurious to their interests. Both these classes of men verge towards extremes which are equally inconsistent and dangerous. The amazing fact, that creation consists of a countless number of magnificent systems and worlds beyond the comprehension of finite minds, ought not thus to be recklessly set aside in our views of God and of religion; for they are all the workmanship of ONE BEING, and they are connected together as parts of ONE grand system, of which the God we profess to worship is the supreme and universal governor. They present to the view of all intelligences the most glorious displays of his character and perfections, and consequently demand from us a corresponding sentiment of admiration and reverence, and a corresponding tribute of homage and adoration. Such enlarged prospects of the universe are therefore available for the loftiest purposes of religion and piety, and ought to enter as an element into all our views of the administration of the Almighty, and of that worship and obedience he requires from his rational offspring, unless we would be contented to render him a degree of homage far inferior to that which the manifestation of his attributes demands.

God is known only by the manifestations which he makes of his character and perfections. The highest created intelligences can know nothing more of the Divinity than what is derived from the boundless universe he has presented to their view, the dispensations of his providence to certain orders of beings, and the special revelations he may occasionally vouchsafe, on certain emergencies, to particular worlds. Had man continued in primeval innocence, the contemplation of the vast creation around him, with all its diversified wonders and beneficent tendencies, would have led him to form correct views of the attributes of his Almighty Maker, and of the moral laws by which his conduct should be regulated: but it does not follow, that because the study of nature is now of itself an insufficient guide

to the knowledge of the Creator and the enjoyment of eternal felicity, such studies are either to be thrown aside, or considered as of no importance in a religious point of view. To overlook the astonishing scene of the universe, or to view it with indifference, is virtually to "disregard the works of Jehovah, and to refuse to consider the operations of his hands." It is a violation of Christian duty, and implies a reflection on the character of the Deity, for any one to imagine that he has nothing to do with God considered as manifested in the immensity in his works; for his word is pointed and explicit in directing the mind to such contemplations. "Hearken unto this; stand still, and consider the wonderful works of God." "Lift up thine eyes on high, and behold who hath created these orbs." "Remember that thou magnify his works which men behold." "Great and marvellous are thy works, Lord God Almighty! Thy saints shall speak of the glory of thy kingdom and talk of thy power, to make known to the sons of men thy mighty operations and the glorious majesty of thy kingdom."

3. The Christian revelation, throughout all its departments, is not only consistent with the views we have taken of the universe, but affords direct evidence of the magnificence of creation, and of the myriads of beings with which it is peopled. Of this position we have exhibited some proofs in the remarks and illustrations contained in Chapter XVII., which show at the same time the harmony which subsists between the discoveries of revelation and the discoveries which have been made in the system of nature. There is no other system of religion or pretended revelation that was ever propagated in the world to which such a characteristic belongs. If we examine the Mahomedan Koran, the Shasters of Bramah, the system of Confucius, the mythology of the Greeks and Romans, and every other Pagan code of religion, we shall find interspersed throughout the whole of them numerous sentiments, opinions, and pretended facts at utter variance with the true system of nature, and to what are known to be the established laws of the universe. This is strikingly exemplified in the extravagant stories and descriptions contained in the pretended revelations of Mahomet, and the absurd notions respecting the creation contained in the sacred books of the Hindoos, which assert that the universe consists of seven heavens and seven worlds, which are all at a future period to be absorbed into God; with many other absurdities. In opposition to all such foolish and absurd opinions, the inspired writings, when properly understood, and rationally interpreted according to the rules of just criticism, are uniformly found to be perfectly consistent with the discoveries of science, and the facts which are found to exist in the system of the universe; and this correspondence and harmony ought to be considered as a strong presumptive evidence that the revelations of Scripture and the scenes of the material universe proceed from the same All-wise and Omnipotent Author.

## CHAPTER XX.

### *On Comets.*

As this class of the celestial bodies forms a part of the solar system, it might have been more appropriate to have introduced the subject into our volume entitled, "Celestial Scenery," which has for its principal object a description of the bodies connected with that system; but as that work swelled to a greater size than was at first foreseen, it was judged expedient to postpone the consideration of comets to the present volume. As our knowledge of these bodies, however, is very limited, and no discoveries have yet been made which might lead us to form a decisive opinion of their nature and destination, I shall content myself with giving a brief detail of some of the leading facts which have been ascertained respecting them.

The word *comet* literally signifies a *hairy star;* because such bodies are generally accompanied with a nebulosity, or train, which has the appearance of luminous hair. The luminous point near the centre of a comet, which is the most brilliant, is called the *nucleus*. The haze or nebulosity which surrounds the nucleus is called the hair, and sometimes the *envelope;* and the nucleus and hair combined constitute what is usually termed the *head* of the comet. The luminous train, extending sometimes to a great distance from the head, is called the *tail* of the comet. These bodies have occasionally appeared in the heavens in all ages. The ancients were divided in their opinion respecting them; some considering them as wandering stars; others, as meteors kindled in the atmosphere of the earth, subsisting for a time, and then dissipated; and others viewed them as prodigies indicating wars, famines, inundations, or pestilences. Aristotle, who believed that the heavens were incorruptible and

unchangeable, maintained that comets were generated when they first made their appearance, and were destroyed when they ceased to be visible, and consequently that they could not be reckoned to belong to the heavenly bodies, but were only meteors or exhalations raised into the upper regions of the air, where they blazed for a while, and disappeared when the matter of which they were formed was consumed. And as the opinions of this ancient sage had a powerful influence on the philosophers and astronomers of later times,—as his assertions were frequently regarded as little short of demonstrations,—few persons had the boldness and independency of mind to call in question the positions he maintained on any subject discussed in his writings.

It was not before the time of the celebrated astronomer, Tycho Brahe, that the nature of comets began to be a little understood, and that they were considered as moving in the planetary regions. This astronomer observed with great diligence the famous comet which appeared in 1577; and, from many accurate observations during the time of its appearance, found that it had no sensible diurnal parallax, and therefore was not only far above the limits of our atmosphere, but beyond the orbit of the moon itself. Its motions were likewise particularly observed by Hagecius, at Prague, in Bohemia, at the same time that they were observed by Tycho, at Uraniburg. These two places differ six degrees in latitude, and are nearly under the same meridian, and both measured the distance of the comet from the same star, which was in the same verticle circle with the comet; yet both observers found their distances the same, and consequently they both viewed the comet in the same point of the heavens, which could not have happened unless the comet had been in a higher region than the moon. After Tycho, Kepler had an opportunity of making observations on the comets which appeared in 1607 and 1618, and from all his observations he deduced this conclusion, "that comets move freely through the planetary orbs." From this period comets began to be more accurately observed, and to be considered as constituent parts of the solar system; and at length the illustrious Newton demonstrated that their motions are performed in long ellipses, having the sun in one of their foci.

Before proceeding to inquire into the nature and physical constitution of these bodies, I shall present the reader with

*A brief sketch of the history of the most remarkable Comets which have appeared in modern times.*

One of the most remarkable comets which have appeared in modern times is that which made its appearance towards the close of the year 1680, and which was particularly observed by most of the astronomers of Europe. This comet, according to the accounts given by the astronomers of that period, appeared to descend from the distant regions of space with a prodigious velocity, almost perpendicular to the sun, and ascended again in the same manner from that luminary with a velocity retarded as it had before been accelerated. It was observed, particularly at Paris and Greenwich, by Cassini and Flamstead, by whom it was seen in the morning from the 4th to the 25th of November, 1680, in its descent towards the sun; and after it had passed its *perihelion*,* in the evening, from the 12th of December to the 9th of March, 1681. The many exact observations made on this comet enabled Sir I. Newton to discover that so much of its orbit as could be traced by the motion of the comet, while it was visible, was, as to sense, a *parabola*, having the sun in its focus, and that it was one and the same comet that was seen all that time. This comet was remarkable for its very near approach to the sun. At its perihelion, it was not above a sixth part of the sun's diameter from its surface; that is, about 146,000 miles from the surface of that luminary, and 584,000 from its centre. According to Sir Isaac Newton, the velocity of this comet when nearest the sun was 880,000 miles an hour. On taking its perihelion distance, as given by M. Pingre, Mr. Squire found, by two different calculations, that its velocity in its perihelion was no less than 1,240,000 miles an hour! This velocity was so great that, if continued, it would have carried it through 124 degrees in an hour; but its actual hourly motion during that interval, before and after it passed the perihelion, was 81 degrees, 47 minutes. At this period, the diameter of the sun, as seen from the comet, must have subtended an angle of more than a hundred degrees, which must nearly have filled its whole hemisphere.

From Dr. Halley's determination of its orbit, it appears that when in its aphelion, or greatest distance from the sun, it cannot be less than 13,000,000,000, or thirteen thousand millions of miles distant from that luminary; that is, seven times the distance of Uranus. According to the same astronomer, this comet, in passing through its southern node, came within the length of the sun's semi-diameter of the orbit of the earth, that is, within 440,000 miles; and he remarks, "had the earth been

* The *perihelion* is that point in the orbit of any planet or comet which is nearest to the sun. It is also called the *lower apsis*. The *aphelion* is that point in the orbit which is furthest from the sun; called, also, the *higher apsis*.

then in that part of its orbit nearest that node of the comet, their mutual gravitation must have caused a change in the plane of the earth's orbit, and in the length of our year; and if so large a body with so rapid a motion were to strike the earth, a thing by no means impossible, the shock might reduce this beautiful frame to its original chaos." Modern observations, however, render such deductions somewhat improbable. The *period* of this comet is supposed to be about 575 years. It is conjectured that it is the same comet which appeared in 1106, in the reign of Henry I., that was seen during the consulate of Lampadius and Orestes, about the year 531, and in the forty-fourth year before Christ, in which year Julius Cæsar was murdered. Its nucleus was computed to be about ten times as large as the moon. Its tail extended over a space of seventy degrees in extent.

This is the comet, to the near approach of which to the earth, Mr. Whiston attributed the universal deluge in the time of Noah. His opinion was, that the earth, passing through the atmosphere of the comet, attracted from it a great part of the water of the flood; that the nearness of the comet raised a great tide in the subterranean waters; that this could not be done without making fissures or cracks in the outer crust of the earth; that through these fissures the subterraneous waters were forced; that along with the water much slime or mud would rise, which, after the subsiding of the water partly into the fissures and partly into the lower parts of the earth to form the sea, would cover over to a considerable depth the antediluvian earth; and thus he accounts for trees and bones of animals being found at very great depths in the earth. The same comet, he supposed, when coming near the earth after being heated to an immense degree in its perihelion, would be the instrumental cause of that great catastrophe, the general conflagration. Modern geological researches, however, render all such hypotheses utterly untenable.

2. Another comet which has obtained a certain degree of celebrity is that which appeared in 1682, and is usually distinguished by the name of *Halley's comet*. This comet appeared with considerable splendour, and exhibited a tail thirty degrees in length. On calculating its elements from its perihelion passage, Dr. Halley was led to conclude that it was identical with the great comets which appeared in 1456, 1531, and 1607, whose elements he had also ascertained. The intervals between these periods being about seventy-five or seventy-six years, he was led to conclude that this was the period of the revolution of the comet, and ventured to predict that it would again return about the latter part of the year 1758. As this was the first comet whose return had been predicted, when the time of its expected appearance approached, astronomers became anxious to ascertain whether the attraction of the larger planets, Jupiter and Saturn, might not interfere with its orbitual motion, and prevent it from arriving at its perihelion so soon as the time predicted. Clairaut, an eminent French mathematician, after many intricate and laborious calculations in reference to the subject, concluded that the attraction of Saturn would lengthen the period 100 days, and the action of Jupiter 518, making in all 618 days, by which the expected return would happen later than if no such influence had taken place; so that instead of the period being 74 years, 323 days, it ought to be 76 years, 211 days; and as the comet passed its perihelion on September 14, 1682, it ought to reach the same point on April 13, 1759. These calculations were read before the Academy of Sciences, on the 14th of November, 1758; but Clairaut gave notice that, being pressed for time, he had neglected in his calculations small values, which collectively might amount to about thirty days in the seventy-six years. These predictions were accordingly verified, for the comet appeared about the end of December, 1758, and arrived at its perihelion on the 13th of March, 1759, only thirty days before the time fixed by the calculations of Clairaut, who, upon repeating the process by which he had arrived at the result, reduced this error to nineteen days. The same comet again made its appearance, according to prediction, in 1835, of which a particular account will be given in the sequel.

3. Another remarkable comet made its appearance in 1744, which excited a considerable degree of attention. It was first seen at Lausanne, in Switzerland, December 13, 1743; from that period it increased in brightness and magnitude as it approached nearer the sun. On the evening of January 23, 1744, it appeared exceedingly bright and distinct, and the diameter of its nucleus was nearly equal to that of Jupiter. Its tail then extended above 16 degrees from its body, and was supposed to be about 23 millions of miles in length. On the 11th of February, the nucleus, which had before been always round, appeared oblong in the direction of the tail, and seemed divided into two parts by a black stroke in the middle. One of the parts had a sort of beard, brighter than the tail; this beard was surrounded by two unequal dark strokes, that separated the beard from the hair of the comet; these odd phenomena disappeared the next day, and nothing was seen but irregular obscure spaces like smoke in the middle of the tail, and the head resumed

its natural form. On the 15th of February, the tail was divided into two branches, the eastern about 8 degrees long, the western 24. On the 23d the tail began to be bent. It showed no tail till it was as near the sun as the orbit of Mars, and it increased in length as it approached nearer that luminary. At its greatest length, it was computed to equal a third part of the distance of the earth from the sun.* This was one of tho most brilliant comets that had appeared since that of 1680. Its tail was visible for a long time after its body was hid under the horizon: it extended 20 or 30 degrees above the horizon, two hours before sunrise.

4. In the month of June, 1770, Messier discovered a comet, the motions of which appear to be involved in a considerable degree of mystery. The comet continued visible for a long time. Lexell ascertained, from observation, that it described an ellipse around the sun, of which the greater axis was only three times the diameter of the earth's orbit, which corresponds with a revolution of 5½ years. It was therefore expected that it would again frequently make its appearance; but it has never since been visible, although it made a pretty brilliant appearance in 1770. The National Institute of France, not many years ago, requested M. Burckhardt to repeat all the calculations with the utmost care; and the result of his labour has been a complete confirmation of the elements obtained by Lexell. What has become of this comet it is difficult to conjecture. Its aphelion, or greatest distance from the sun, was reckoned to be not far beyond the orbit of Jupiter, and that it approached as near to the earth as the moon, and ought to have appeared twelve times since the year 1770. M. Arago attempts to solve the difficulty by affirming that its orbit was then totally different from that which it has since pursued; that its passage to the point of perihelion in 1776, when it was expected, took place by day, and before the following return, the form of the orbit was so altered that had the comet been visible from the earth, it would not have been recognized; that before 1767, during the whole progress of its revolutions, its shortest distance from the sun was 199,000,000 leagues, and that after 1779, the minimum distance became 131,000,000 leagues, which was still too far removed for the comet to be perceptible from the earth. Sir David Brewster attempts to account for its disappearance by supposing that it must have been attracted by one of the planets whose orbit it crossed, and must have imparted to it its nebulous mass; and that it is probable the comet passed near Ceres and Pallas, and imparted to them those immense atmospheres which distinguish them from all the other planets. Whether any of these opinions be tenable and sufficient to solve the difficulty, is left entirely with the reader to determine.

5. Another comet, which has engaged the particular attention of astronomers during the last twenty years, is distinguished from all preceding comets by the *shortness of its periodic revolution.* It is usually denominated *Encke's comet*, so called from Professor Encke, of Berlin, who first ascertained its periodical return. It was discovered at Marseilles, on the 26th November, 1818, by M. Pons, and its parabolic elements were presented to the Board of Longitude, at Paris, by M. Bouvard, on the 13th of January, 1819. It was immediately remarked that the result of Bouvard's calculations was too similar to the elements of a comet which appeared in 1805, not to consider that and the one of 1818 as the same body; and M. Encke soon after established, by incontestable calculations, that this comet took only about 1200 days, or three years and three-tenths, to travel through the whole extent of its elliptic orbit. This was considered as a very extraordinary result, as an opinion had previously prevailed that the period of a revolution of a comet must *necessarily* be long. It now appears that this comet was first seen by Messier and Mechain in 1786; afterwards by Miss Herschel in 1795; and its subsequent returns were observed by different astronomers in 1805 and 1819, all of whom, at those periods, supposed that the four comets were four different bodies. The elements of this comet, and the short period of its revolution, are now incontrovertibly established; for its reappearance in the southern hemisphere in June, 1822, took place very nearly in the positions previously calculated. The agreement was not less remarkable in 1825; and in 1828, the third period of its announced return, it occupied the places assigned to it by Encke the year preceding. It likewise appeared in 1832, 1835, and 1838.

This comet is very small; its light is feeble; it has no tail; it is invisible to the naked eye, except in very favourable circumstances, but may be seen with a small magnifying power. It revolves in an elliptical orbit of considerable eccentricity, having an inclination to the plane of the elliptic of 13⅓ degrees. On comparing the intervals between the successive perihelion passages of this comet, a singular fact has been elicited, namely, that its periods are continually diminishing, and its mean distance from the sun shortening by slow but regular degrees. This is supposed by M. Encke to be produced by a resistance experienced by the comet from a very rare ethe-

* Memoirs of the Academy of Sciences for 1744.

real medium pervading the regions through which it moves; since such resistance, by diminishing its actual velocity, would diminish also its centrifugal force, and thus give the sun more power over it to draw it nearer. It is therefore the opinion of Sir J. Herschel, that "it will probably fall ultimately into the sun, should it not first be dissipated altogether, a thing no way improbable, when the lightness of its materials is considered, and which seems authorized by the observed fact of its having been less and less conspicuous at each reappearance." The acceleration of this comet is about two days in each revolution; and the frequent opportunities of observation which will occur, in consequence of the shortness of its period, may lead to new and interesting conclusions in relation to the nature of these bodies.

6. Besides the above, another periodical comet has lately been discovered, which is distinguished by the name of *Biela's* and sometimes *Gambart's comet.* This comet was perceived at Johanisberg, on the 27th Feb. 1826, by M. Biela; and by M. Gambart, at Marseilles, ten days afterwards. Gambart, without delay, calculated its parabolic elements from his own observations, and by inspecting a general table of comets, he recognized that it was not its first appearance, but that it had been already observed in 1789. and 1795. Messrs. Clausen and Gambart undertook the computation of the comet's revolution, and found, each of them nearly at the same time, that the new comet made its entire revolution round the sun in a period of about seven years. It was afterwards found, more accurately, to be 2460 days, or nearly 6¾ years. M. Damoiseau calculated the perturbations of this comet, and predicted that it would cross the plane of the earth's orbit on the 29th of October, 1832, *a little before midnight,* at a point about 18,480 miles within the orbit of the earth. According to this prediction, the comet actually made its appearance in 1832 about the time now specified. Its next appearance was calculated to happen in 1839; and it was reckoned that it would arrive at its perihelion on the 23d July of that year.

The predicted appearance of this comet in 1832 seems to have produced considerable alarm, particularly in France. Some German journalists predicted that it would cross the earth's orbit near the point at which the earth would be at the time, and cause the destruction of our globe. Such was the degree of alarm excited on this occasion, that M. G * * *, a Professor in Paris, put the question to the Academy of Sciences, whether it did not feel itself bound in duty to refute, as speedily as possible, this assertion. "Popular terrors," he observed, "are productive of serious consequences. Several members of the Academy may still remember the accidents and disorders which followed a similar threat, imprudently communicated to the Academy by M. de Lalande, in May, 1773. Persons of weak mind died of fright, and women miscarried. There were not wanting people who knew too well the art of turning to their advantage the alarm inspired by the approaching comet, and *places in paradise were sold at a very high rate.* The announcement of the comet of 1832 may produce similar effects, unless the authority of the Academy apply a prompt remedy; and this salutary intervention is at this moment implored by many benevolent persons." It was supposed by some, that if any disturbing cause should delay the arrival of the comet for one month, the earth must pass directly through its head.

In order to dispel such fears, and to illustrate the nature of these bodies, M. Arago published an excellent and popular treatise on comets in the "*Annuaire*" of 1832. He showed that the result of the calculation was, that the passage of the comet ought to proceed *a little within our orbit,* and at a distance from that curve, which is equal to *four terrestrial radii and two-thirds,* or about 37,000 miles; that on the 29th October, 1832, *a portion of the earth's orbit* might be included within the nebulosity of the comet; but that the earth would not arrive *at the same point* of its orbit till the morning of the 30th November, or more than a month afterwards; and consequently that the earth would be more than twenty millions of French leagues (or fifty millions of British miles) distant from the comet. He adds, that "if the comet, instead of crossing the plane of the ecliptic on the 29th October, had not arrived there till the morning of the 30th November, it would have undoubtedly mingled its atmosphere with ours, and perhaps even have struck us!" The earth is considered in more danger, if danger there be, from this comet and that of Encke than from any other. Encke's comet crosses the orbit of the earth sixty times in the course of a century, and there is certainly a *possibility* that it might come into collision with the earth, but the probability of its doing so is very small; and, besides, this comet and that of Gambart are so extremely rare, that little danger is to be apprehended, even although a contact were to take place. Gambart's is a small, insignificant comet, without a tail, or any appearance whatever of a solid nucleus, and is not distinguishable by the naked eye.

7. *The Comet of* 1807. This was the first comet on which I had an opportunity of making observations. My first observation

was on the evening of October the 8th, 1807, a little after sunset, when it appeared in a north-westerly direction, not far distant from Arcturus, which was then only a little above the horizon. To the naked eye it appeared somewhat like a dim nebulous star of the second magnitude, with a beam of light on one side of it. Through a telescope, its tail presented a pretty brilliant appearance, and occupied a space of considerably more than a degree in length. The coma seemed to have a roundish, but dim and undefined appearance, and appeared more indistinct as the magnifying power was increased. When viewed with an achromatic telescope of thirty-one inches focal distance, and a power of thirty, it presented a very distinct and beautiful appearance, and the nucleus, coma, and tail, nearly filled the field of view. When a power of sixty was applied, it was much more indistinct than with the former power, and in all the subsequent observations the lower power was generally preferred. In the course of five or six weeks, or about the middle of November, it disappeared to the naked eye. I traced it with the telescope, as often as the weather would permit, for two or three months after it had become invisible to the unassisted sight, and found that its apparent motion was pretty rapid, and towards the north-east. About the middle of January, 1808, at eleven P. M., it appeared in a direction north-east by north; and at this time it appeared through the telescope like a small nebulous star, or like those species of comets called *bearded* comets, having no trace of any thing similar to a tail. The last time I saw it was about the end of January, when it was still distinctly visible, like a nebulous star; but cloudy weather for nearly a fortnight prevented any further observations, and I saw it no more. On the evening in which I had the last peep of it, I detected another comet within eight or ten degrees of it, which appeared like a star of the third magnitude, and exhibited a pretty brilliant appearance through the telescope. It had no tail, like the former comet, but appeared surrounded with radiant hairs like the *glory* which painters represent around the head of our Saviour. It continued visible for several weeks; but I have not seen any particular notices of this second comet, or any special observations on it, which have been recorded by astronomers.

This comet appears to have been first noticed by Herschel and Schroeter about the 4th of October, 1807, who continued their observations upon it for several months. According to Schroeter's observations and estimates, the diameter of the nucleus of this comet was about 4600 miles, or nearly the size of the planet Mars, and appeared to be of considerable density; the diameter of its coma, 120,000 miles, but liable at different times, to variations of increase and decrease; and its rate of motion, at certain periods, 1,333,380 miles a day, or 55,557 miles an hour. Its tail was divided in a very unusual manner into two separate branches; the north side continued much brighter and better defined than the other, and was also invariably convex, while the other side was concave. But what was deemed most remarkable was the variation in length and the *coruscations* of the tail. Something like coruscation had been observed by the naked eye in the case of preceding comets, and such phenomena appear to have been confirmed by the observations of Schroeter. In less than one second, streamers shot forth to two and a half degrees in length; they as rapidly disappeared and issued out again, sometimes in proportions and interrupted like our northern lights. Afterwards the tail varied both in length and breadth, and in some of the observations, the streamers shot from the whole expanded end of the tail, sometimes here, and sometimes there, in an instant, two and a half degrees long, so that within a single second they must have shot out a distance of 4,600,000 miles. Their light was also sometimes whiter and clearer at the end than at the base, as is occasionally seen in the northern lights. Some have objected to the extreme rapidity of the streamers as here stated, but the fact of coruscations having been seen appears to be confirmed by the observations of this celebrated and accurate observer. The observations of Herschel on this comet differ in some respects from those of Schroeter, particularly in the estimate he makes of the size of the nucleus, which he reckons to be considerably smaller than what has been stated above.

Fig. 78 is a view of this comet as seen on the night of October 21st by Schroeter. Fig. 79 is a view of the same comet as seen by Bessel, October 22d, at eight in the evening; both which exhibit its divided tail.

8. The most remarkable comet which has appeared in modern times, since that of 1680, was *the comet of* 1811. About the beginning of September in that year, about eight or nine in the evening, as I was taking a random sweep with my telescope over the north-western quarter of the heavens, an uncommon object appeared to pass rapidly across the field of view, which on examination appeared to be a splendid comet. Not having heard of the appearance of any such body at that time, I was led to imagine that I had fortunately got the first peep of this illustrious stranger; but I afterwards learned from the public prints that it had been seen a day or two before by Mr. Neitch, in the neighbourhood of Kelso,

who appears to have been the first that observed it in this country. This comet appeared with peculiar splendour, and was visible, even to the naked eye, for more than three months in succession, and excited universal attention. It afforded to astronomers more opportunities for observation of its physical aspect and constitution, and for determining the elements of its orbit, than almost any other comet that had previously appeared. The two celebrated observers, Herschel and Schroeter, made numerous and very particular observations on the phenomena and motions of this comet, which were continued every clear evening for the space of nearly five months. Some of these observations, along with the remarks and deductions connected with them, are extremely interesting to the astronomical observer; but my limits will permit only a statement of the general results.

Fig. 78.

Some of the results deduced by Schroeter are the following:—That the central globe of light, or what he calls the nucleus, was 50,000 miles in diameter, or nearly six and a half times the diameter of the earth, which he deduced from the mean of twenty-seven measurements, which gave 1′ 49″ as the mean angular diameter of the body; that this great body was in all probability chiefly fluid, though its central parts might consist of denser substances; and that there was reason to believe that it shone with its own native light. The *coma* was extremely rarefied in comparison with the nucleus, resembling a very faint whitish light, scattered in separate portions. It was divided into two; one immediately encompassing the nucleus, the other of a more faint and grayish light, sweeping round it at a distance, and forming the double tail which the comet presented. The *train*, or *head veil*, as he terms it, swept around the nucleus, at a distance equal to its breadth, and appeared as unconnected as the ring of Saturn with its body, and which sometimes appeared darker than the open sky. The diameter of the exterior part of the head was 34′ 15″, or about 947,000 miles, which is larger than the diameter of the sun, and which he thinks must have formed a hollow cone around the nucleus, and which he thought indicated a force of a repulsive nature residing in the nucleus. Between the 4th and 5th of December a great revolution took place; the rarefied nebulous matter, which had for three months been so unusually repelled from the nucleus on every side, to a distance of about one-fifth of the diameter

of the head, or 190,000 miles, was again attracted to it, affording an incontrovertible proof of physical action upon a great scale, arising doubtless from the same causes which produce the other phenomena of nature. The double tail of this comet was exceeding faint compared with the nucleus and coma. On the 23d of October, it extended fully eighteen degrees, notwithstanding its oblique position, the angle at the sun being then 61° 23′; at the earth, 69°; and at the comet, 49° 37′. Had it been viewed at right angles, it would have subtended an angle of 36° 36′, equivalent to more than 60,000,000 of miles, which is more than half the distance from the earth to the sun. *Coruscation*, similar to those which appeared in the tail of the comet of 1807, were likewise perceived, particularly on October the 16th, when a small tail instantaneously appeared, then vanished, and reappeared, which was in length equal to three times the diameter of the comet's head, or 2,373,000 miles. Other displays of the same kind took place on the 7th of November and the 18th of December. These facts, of the reality of which Schroeter entertained not the least doubt, must be considered as very curious and extraordinary phenomena.*

Herschel's observations nearly agree with those of Schroeter, excepting that he estimates the diameter of the nucleus as very much smaller than what is stated above. He estimates the *greatest length* of the tail, as seen on the 15th of October, to have been 100,000,000, or a hundred millions of miles, which consequently extended over a space larger than that which intervenes between the earth and the sun; and its *breadth*, as deduced from the observations of October the 12th, nearly fifteen millions of miles. He calculated its distance when nearest to the earth to be about 113 millions of miles. He concluded that the solid matter of the comet was spherical, that it shone in part by its own native light, and that it probably had a rotation round its axis. From the most accurate observations of the motion of this comet, its period of revolution has been calculated to exceed 3000 years. Bessel computes it at 3383 years; and several other astronomers conceive its period to be considerably longer, even exceeding 4000 years.

9. *Reappearance of Halley's Comet in* 1835. The return of this comet was calculated by Messrs. Damoiseau and Pontecoulant; the former of whom calculated its return to the perihelion on the 4th, and the latter on the 7th of November, 1835, and it actually arrived at that point only a few days after these periods, namely, on the 16th of November. It was first seen on the continent in the month of August that year, but does not appear to have been noticed in the northern parts of Britain till more than a month afterwards. Its expected reappearance excited universal attention throughout Europe. Soon after the middle of September, as I was taking a sweep with a two-feet telescope over the north-eastern quarter of the heavens, near the point where I expected its appearance, I happened to fix my eye on this long-expected visiter, which appeared very small and obscure. I immediately directed an excellent three and a half feet achromatic telescope, with a diagonal eye-piece, magnifying about thirty-four times, to the comet, when it was distinctly seen, and appeared of a considerable diameter, but still somewhat hazy and obscure. I afterwards applied a power of forty-five, and another of ninety-five; but it was seen most distinctly with the lower power. With ninety-five it appeared extremely obscure, and nearly of the apparent size of the moon.† There appeared at this time nothing like a tail, but

* Having referred, on various occasions, to the observations of that indefatigable astronomer, *Schroeter*, of Lilienthal, it may not be uninteresting to some readers to insert the account of the losses he sustained by the burning and plunder of his observatory, as expressed in his own pathetic language:

"At length, after the most touching afflictions of mortality, I once more awake in my temple consecrated to the Eternal Godhead, and am again able, after a total derangement of my affairs, to edit these collections concerning the great comet of 1811. Through the most barbarous fury, in consequence of an equally barbarous decision, the whole innocent soft vale of Lilies [the signification of the name of Lilienthal, where his observatory was situated] was burnt to the ground, without any previous examination. They likewise burnt down the royal government buildings. I lost my whole movable property, and, what was most sensibly felt by me, amongst it, with a considerable loss also to the booksellers of Europe, the sole copy of the whole of my works and writings deposited in the government house. Even my observatory preserved by Providence from the fire, was a few days afterwards broken into, plundered, and shamefully thrown into confusion by demolishing the clocks, breaking off the finders from the instruments, and carrying off the smaller instruments. Previously, indeed, having been removed from my post, my income had gradually become so very straitened, I was obliged to forego all but the most necessary outlays, and to give myself up to a scientific slumber. Under the endurance of these troubles all my scientific patrons and friends will doubtless, as far as possible, excuse me, if through melancholy, and on account of the extraordinary high rate of postage, I have been compelled to put out of sight so many obligations of courtesy; for to the present time every thing is so straitened with me that my observatory, from want of time and heavy expenses is for the most part a confusion.

"JOH. HIERONYM. SCHROETER."

"*Lilienthal*, Jan. 22, 1815."

Schroeter did not long survive the calamity alluded to above. He died on the 29th of August, 1816, in the 71st year of his age.

† In viewing comets, telescopes with large apertures and comparatively low magnifying powers should generally be used, as the faint light emit-

the central part was much more luminous than the other portions of the comet, and presented something like the appearance of a star of the third or fourth magnitude surrounded with a haze. In some of the views I took of this object, the luminous part or nucleus appeared to be considerably nearer one side than another. At this period, and for a week or ten days afterwards, the comet was altogether invisible to the naked eye. Many subsequent observations were made, and published in the provincial newspapers, but which my present limits prevent me from inserting.

After the comet became visible to the naked eye, the tail began to appear, and increased in length as it approached its perihelion, and at its utmost extent was estimated to be above thirty degrees in length. On the 13th of October, according to the observations of Arago, a luminous sector was visible in its head; on the day following, the sector had disappeared, and a more brilliant one and of greater longitudinal extent was formed in another place. This second sector was observed on the 17th, when it appeared less bright; and on the 18th its weakness had decidedly increased. The comet was concealed till the 21st, but on that day three distinct sectors were visible in the nebulosity. On the 23d, all traces of these sectors had disappeared, the nucleus, which had previously been brilliant and well-defined, having become so large and diffuse that the observer could scarcely believe in the reality of such a sudden and important alteration, till he satisfied himself that the appearance was not occasioned by the moisture on the glasses of his instrument. It appears, likewise, that one of these luminous fans or sectors was observed by Sir J. Herschel, at the Cape of Good Hope, after the comet had passed its perihelion. The nebulosity of this comet appears to have increased in magnitude as it approached the sun, but its changes were sometimes unaccountably rapid. On one occasion it was observed to become obscure and enlarged in the course of a few hours, though a little before, its nucleus was clear and well-defined. On the 11th of October, the Rev. T. W. Webb, and two other observers, observed *coruscations* in the tail. On that evening, at $7^h\ 30'$, the tail was very conspicuous, extending between $\varkappa$ and $\gamma$ Draconis, and evidently fluctuated, or rather coruscated, in length, being occasionally short, and then stretching in the twinkling of an eye to its full extent, which was at least equal to ten degrees. Its changes were extremely similar to the kindling and fading of a very faint streamer of the Aurora Borealis.

ted by comets, whether it be inherent or reflected, will not permit the use of so high magnifying powers as may be applied to the planets.

"The influence of the ethereal medium on the motion of Halley's comet will be known after another revolution, and future astronomers will learn, by the accuracy of its returns, whether it has met with any unknown cause of disturbance in its distant journey. Undiscovered planets beyond the visible boundary of our system may change its path and the period of its revolution, and thus may indirectly reveal to us their existence, and even their physical nature and orbit. The secrets of the yet more distant heavens may be disclosed to future generations by comets which penetrate still further into space, such as that of 1763, which, if any faith may be placed in the computation, goes nearly 43 times further from the sun than Halley's does, and shows that the sun's attraction is powerful enough at the distance of 144,600 millions of miles to recall the comet to its perihelion. The periods of some comets are said to be many thousand years, and even the average time of the revolution of comets generally is about a thousand years; which proves that the sun's gravitating force extends very far. La Place estimates that the solar attraction is felt throughout a sphere whose radius is a hundred millions of times greater than the distance of the earth from the sun." "The orbit of Halley's comet is four times longer than it is broad; its length is about 3420 millions of miles, about 36 times the mean distance of the earth from the sun. At its perihelion it comes within 57 millions of miles of the sun, and at its aphelion it is 60 times more distant. On account of this extensive range, it must experience 3600 times more light when nearest to the sun than in the most remote point of its orbit. In the one position the sun will seem to be four times larger than he appears to us, and at the other he will not be apparently larger than a star.*

The appearance of this comet, so near the time predicted by astronomers, and in positions so nearly agreeing with those which were previously calculated, is a clear proof of the astonishing accuracy which has been introduced into astronomical calculations, and of the soundness of those principles on which the astronomy of comets is founded. It likewise shows, that comets, in general, are *permanent* bodies connected with the solar system, and that no very considerable change in their con-

* Mrs. Somerville's "Connexion of the Physical Sciences," a work which, though written in a popular style, would do honour to the first philosophers of Europe. Of this lady's profound mathematical work on the "Mechanism of the Heavens," the Edinburg Reviewers remark—"It is unquestionably one of the most remarkable works that female intellect ever produced in any age or country; and with respect to the present day, we hazard little in saying, that Mrs. Somerville is the only individual of her sex in the world who could have written it."

stitution takes place while traversing the distant parts of their orbits.*

From the preceding historical sketches and descriptions, the reader will learn something of the *general phenomena* of comets; and I shall now briefly inquire into the opinions which have been formed respecting the

PHYSICAL CONSTITUTION OF COMETS.

On this subject our knowledge is very imperfect; in fact, we may be said to know little or nothing of the physical construction of those mysterious bodies, or of the nature of the substances of which they are composed. In regard to the *nebulosity* of comets, where there appears no nucleus, it has been conjectured to be composed of something analogous to globular masses of vapour, slightly condensed towards the centre, and shining either by inherent light or by the reflected rays of the sun. When there is a nucleus in the centre of a comet, it seldom happens that the nebulosity extends to it with a gradually increasing intensity. On the contrary, the parts of the nebulosity near the nucleus are but slightly luminous, and seem to be extremely rarefied and transparent. At some distance from their centre, their shining quality is suddenly increased, so that it looks like a ring of invariable size resting in equilibrium around the centre. Sometimes two, and even three of these concentric rings have been perceived separated by intervals; but what appears to be a ring must in reality be a *spherical covering*, an idea of which may be formed by imagining, in our atmosphere, at three different heights, three continued layers of clouds entirely covering the globe. The matter of the nebulosity is so rare and transparent that the smallest stars may frequently be seen through it.

As to the *nucleus*, it is generally considered as the solid or densest part of the comet. The *nuclei* of comets are sometimes very similar to the disks of planets, both in form and brightness. They are generally small compared with the whole size of the comet; but in some cases they are of considerable magnitude, as we have already stated in respect to the comets of 1807 and 1811. Some suppose that the nuclei of comets are transparent, as well as their nebulosities, and allege as a proof that stars have been seen through a nucleus. Thus, Montaigne is said to have seen a star of the sixth magnitude through the nucleus of a small comet, and Olbers saw a star of the seventh magnitude, although it was covered by a comet, and without its light being rendered less powerful, but the accuracy of such observations has been called in question. On the other hand, it has been concluded that the nucleus of a comet has on several occasions eclipsed a star which was in the same line of vision. Messier, when observing the small comet of 1774, perceived a star which was eclipsed by the opaque body of a comet, or at least, all the circumstances attending it led to that conclusion. On the 28th of Nov. 1828, at $10^h\ 30'$ P.M., M. Wartmann, at Geneva, perceived a star of the eighth magnitude completely eclipsed by Encke's comet. Comets have likewise been observed to transit the disk of the sun like dark spots. M. Gambart, of Marseilles, calculated that a comet which he had observed would pass across the sun on the morning of the 18th of November, 1826, and both he and M. Flaucerques were successful in obtaining a sight of it during its transit. Mr. Capel Llofft, on the 6th June, 1818, at 11 A.M., saw a body passing over the sun's disk, which appears to have been a comet. It was likewise seen on the same day by Mr. Acton, at $2^h\ 30'$, considerably advanced beyond the point in which it was seen at 11 A.M., and its progress over the disk seems to have exceeded that of Venus in transit. These observations seem evidently to indicate that some comets at least have nuclei composed of solid and opaque materials. From all the observations in relation to this point, collected by M. Arago, he deduces the following conclusions: 1. That there exist some comets destitute of the nucleus. 2. That there are other comets, the nuclei of which are transparent. 3. That there are also comets, which are more brilliant than the planets, the nuclei of which are probably solid and opaque.

In respect to the *tail*, or luminous train which generally accompanies comets, it is found that it is *generally* in opposition to the sun, or on the prolongation of the line which would join the sun and the nucleus. But this is not always the case. Sometimes the direction of the tail has been found at right angles with this line; and in some extraordinary instances, the tails of comets have been observed to point directly towards the sun. This was the case with a comet that appeared in 1824, which for about eight days exhibited an additional luminous train in opposition to that which assumed the ordinary

* The most particular observations on Halley's comet, during its appearance in 1835, which I have seen, are those which were made by the Rev. T. W. Webb, of Tretire, near Ross, an account of which, with deductions and remarks, was read to the Worcestershire Natural History Society. The observations were made with an excellent achromatic telescope by Tulley, of 5 feet 6 inches focal length, and 4 7-10 inches aperture. Through the kindness of this gentleman I was favoured with a manuscript copy of these observations, and would have availed myself of many of his judicious remarks, had my limits permitted.

direction. This anomalous tail, according to Olbers, was 7° long, while the other was only 3½°, and it was bright enough to be seen with an opera-glass. In general, however, it is found that the tail inclines constantly towards the region last quitted by the comet, as if in its progress through an ethereal medium, the matter forming it experienced more resistance than that of the nucleus. The tail is generally enlarged in proportion to its distance from the head of the comet, and in certain cases it is divided into several branches, as already noticed of the comet of 1807. Some have supposed that the divided tail is nothing more than a perspective representation of the sides of a great hollow cone; but there are certain observations which seem to prove that, in some cases, they have a separate existence as independent branches. The most remarkable instance of a divided tail was in the comet of 1744. On the 6th and 7th of March, there were six branches in the tail, each of them about 4° in breadth, and from 30° to 40° long. Their edges were pretty well defined and tolerably bright; their middle emitted but a feeble light, and the intervening spaces were as dark as the rest of the firmament. The tails of comets, as already noticed, sometimes cover an immense space in the heavens. The comet of 1680 had a tail which extended to 68°, that of 1811 to 23°, and that of 1769 to 97° in length; so that some of these tails must have reached from the zenith to the horizon. The length of the tail of the comet of 1680, estimated in miles, was 112,750,000; that of 1769, 44,000,000; and that of 1744, 8,250,000 miles. A body moving at the rate of 20 miles every hour would not pass over the space occupied by the tail of the comet of 1680 in less than 643 years. It has been supposed by some astronomers that certain changes in the appearance of the tails of comets arise from the rotation of the cometary body; as some comets have been supposed to rotate about an axis passing through the centre of the tail, such as that of 1825, which was concluded from certain appearances, to perform its rotation in 20 hours, 30 minutes.

As to the nature of the immense tails of comets, their origin, or the substances of which they are composed, we are entirely ignorant, and it would be wasting time to enter into any speculation on this subject, as nothing could be presented to the view of the reader but vague conjectures, gratuitous hypotheses, and unfounded theories.

MISCELLANEOUS REMARKS ON COMETS.

1. *Whether comets shine with their own native light, or derive their light from the sun?*—This is a question about which there have been different opinions, and at the present moment it may be considered as still undetermined, though the probability is, that in general, they derive their light from the same source as the planets. It appears to have been the opinion of both Schroeter and Herschel, that the comet of 1811 shone by inherent light; and the rapid variations which have been observed in the brightness of the nucleus, and the coruscations of the tail, are considered by some as inexplicable on any other hypothesis. It is likewise supposed that certain phenomena which have been observed in the case of faint and rarefied comets tend to corroborate the same position. For example, Sir J. Herschel, on September 23, 1832, saw a small group of stars of the 16th and 17th magnitude through the comet of Biela. Though this group could have been effaced by the most trifling fog, yet they were visible through a thickness of more than 50,000 miles of cometary matter; and therefore it is supposed scarcely credible that so transparent a material, affording a free passage to the light of such minute stars, could be capable of arresting and reflecting to us the solar rays. On the other hand, it has been objected to this opinion, that comets have appeared as dark spots on the disk of the sun; that their light exhibits traces of *polarization;* and that they have been occasionally observed to exhibit *phases.* M. Arago remarks, that "on the very day that any comet shall appear with a distinct phase, all doubts on this subject will have ceased." But it is considered doubtful whether any *decided phase* has yet been perceived, although some observers were led, from certain phenomena, to infer that something like a phase was presented to their view. It is found that all direct light constantly divides itself into two points of the same intensity when it traverses a crystal possessing the power of double refraction; reflected light gives, on the contrary, in certain portions of the crystal through which it is made to pass, two images of unequal intensity, provided the angle of reflection is not 90°; in other words, it is *polarized* in the act of reflection. On this principle, M. Arago pointed out a phometrical method of determining whether comets borrow their light from the sun, or are luminous in themselves. On the 23d of October, 1835, having applied his new apparatus to the observation of Halley's comet, he immediately saw two images presenting the complementary colours, one of them red, the other green. By turning the instrument half round, the red image became green, and *vice versa.* He concluded therefore that the light of the comet, at least the whole of it, is not composed of rays possessing the property of direct light, but con-

sists of that which is *polarized* or reflected specularly: that is, of light derived from the sun. These experiments were repeated with the same result by three other observers in the Observatory of Paris.

2. It appears to be a remarkable fact in respect to comets, that *the real diameter of the nebulosity increases proportionably as the comet* BECOMES DISTANT *from the sun.* Hevelius appears to have been the first who made this observation; but it seems to have been overlooked, and even an opposite position maintained. As the tails of comets increase in length as they approach their perihelia, so it was generally considered that the nebulosities followed the same law; but the observations which have lately been made on Biela's comet have confirmed the observations of Hevelius. On the 28th of October, 1828, this comet was found to be nearly three times further from the sun than on the 24th of December, or in the proportion of 1.4617, to 0.5419, yet in October its diameter was about twenty-six times greater than in December, or in the proportion of 79.4 to 3.1; that is, its solid contents on the 28th of October were 16,800 times greater than on the 24th of December, and the *smallest* size of the comet corresponded to its *least* distance from the sun. M. Valz, of Nimes, and Sir John Herschel have attempted to account for this circumstance on very different principles, but neither hypothesis appears to be satisfactory.

3. *Whether a comet may ever come in contact with the earth, and produce a concussion?*—As comets move in orbits which form extremely elongated ellipses; as they move in all imaginable directions; as they traverse almost every part of the solar system in returning from the furthest verge of their excursions; as they penetrate within the interior of the planetary orbits—even within the orbit of Mercury, and cross the orbits of the earth and the other planets, *it is not impossible* that a comet may come in contact with our globe. An apprehension of such an event produced a considerable degree of alarm on the Continent at different periods, particularly in 1773 and 1832, as formerly stated. But when we consider the immense cubical space occupied by the planetary system in which the comets move, and compare it with the small capacities of these bodies; and when we take into view certain mathematical calculations in reference to the subject, the probability of a shock from a comet is extremely small. "Let us suppose," says Arago, "a comet of which we only know that at its perihelion it is nearer the sun than we are, and that its diameter is *one-fourth* of that of the earth, the calculation of probabilities shows that of 281,000,000 of chances there is only one unfavourable, there exists but one which can produce a collision between the two bodies. As for the *nebulosity*, in its most general dimensions, the unfavourable chances will be from ten to twenty in the same number of two hundred and eighty-one millions. Admitting then, for a moment, that the comets which may strike the earth with their nuclei would annihilate the whole human race, then the danger of death to each individual, resulting from the appearance of an *unknown* comet, would be exactly equal to the risk he would run if in an urn there was only one single white ball of a total number of 281,000,000 balls, and that his condemnation to death would be the inevitable consequence of the white ball being produced at the first drawing."

When we consider that a Wise and Almighty Ruler superintends and directs the movements of all the great bodies in the universe, and the erratic motions of comets among the rest; and that no event can befall our world without his sovereign permission and appointment, we may repose ourselves in perfect security that no catastrophe from the impulse of celestial agents shall ever take place but in unison with his will, and for the accomplishment of the plans of his universal providence. At the same time, the *possibility* of a shock from a large comet shows us that this earth and all its inhabitants are dependent for their present existence and comforts on the will of an Almighty Agent, "in whom we live, and move, and have our being;" and that were it conformable to his allwise and eternal designs, he could easily disarrange the structure of our globe, and reduce its inhabitants either to misery or to complete destruction; and that, too, without altering a single physical law which now operates throughout the universe.

If we recognize the Scriptures as a revelation from God, we may rest assured that no danger from such a cause can happen to our world for ages yet to come; for there are many important predictions contained in revelation which have not yet received their accomplishment, and must be fulfilled before any fatal catastrophe can happen to our globe. It is predicted that the Jews shall be brought into the Christian church "with the fulness of the Gentiles,"—that "the idols of the nations shall be abolished,"—that "wars shall cease to the ends of the earth,"—that the kingdom of Messiah shall extend over all nations,—that "the knowledge of Jehovah shall cover the earth, and that all shall know him from the least to the greatest,"—that "the earth shall yield its increase," and its desolate wastes be cultivated and inhabited,—that moral order shall prevail, and "righteous-

ness and praise spring forth before all the nations,"—and that this happy era of the world shall centinue during a lapse of ages. These events have not yet been accomplished, though at the present moment they appear either in a state of commencement or of progression; but they cannot be supposed to be fully realized till after a lapse of centuries. The believer in Divine revelation, therefore, has the fullest assurance that, whatever directions comets may take in their motions towards the centre of our system, none of them shall be permitted to impinge upon our globe, or to effect its destruction, for at least a thousand years to come, or till the above and other predictions be completely accomplished.

4. Another question occurs on this subject—namely, *whether any comets have ever fallen into the sun?*—It was the opinion of Sir Isaac Newton that one purpose for which comets are destined is, to recruit the sun with fresh fuel, and repair the great consumption of his light by the streams continually emitted every way from that luminary; and that such comets as come very near the sun in their perihelions meet every time with so much resistance from his atmosphere as to abate their projectile force; by the constant diminution of which, the centripetal power, or gravitation towards the sun, would be so increased as to make them fall into his body. On a similar principle, Arago supposes that the comet of 1680, which approached so near the body of the sun, must have passed nearer to his surface at that time than at its preceding apparitions; that the decrease in the dimensions of the orbit will continue on each succeeding return to its point of perihelion; and that "*it will terminate its career by falling upon the sun.*" But he acknowledges that, "from our ignorance of the densities of the various strata of the sun's atmosphere, of that of the comet of 1680, and of the time of its revolution, it will be impossible to calculate after how many ages this extraordinary event is to happen;" and he likewise admits that "the annals of astronomy do not afford any reason to suppose the previous occurrence of such an event since the origin of historical record;" so that we have no direct evidence that such an event has ever taken place, or that it ever will. We know too little of the physical constitution of the sun, and of the nature of comets, to be able to assert that the falling of a comet into the sun would actually recruit the luminous matter of which his outer surface is composed; for we have reason to believe that there is little or no analogy between the mode in which we supply our fires by means of fagots, and that by which the solar light is recruited and preserved in its pristine vigour; and besides, it is found that bodies, particularly in certain electric states, may be rendered luminous without the addition of any extraneous body to their substances.

### OF THE INFLUENCE OF COMETS ON THE EARTH.

In former times the appearance of comets was supposed to be the forerunner of wars, revolutions, famine, pestilence, the deaths of great men, earthquakes, inundations and other calamities. When the splendid comet of 1456 appeared, (supposed to be the same as Halley's comet,) its tail extended at one time over more than 60 degrees. Three days before its perihelion, its nucleus was as bright as a fixed star, its tail of the colour of gold, and it appears to have exhibited coruscations. Pope Calixtus, believing it to be at once the sign and instrument of Divine wrath, was so frightened at its appearance that he ordered public prayers to be offered up in every town, and the bells to be tolled at the noon of each day, to warn the people to supplicate the mercy of Heaven. He at the same time excommunicated both the comet and the Turks, whose arms had lately proved victorious against the Christians, and established the custom, which still exists in Catholic countries, of ringing the church bells at noon. In modern times, certain natural effects have likewise been attributed to the influence of comets; such as tempests, hurricanes, volcanic eruptions, cold or hot seasons, overflowings of rivers, fogs, dense clouds of flies or locusts, the plague, the dysentery, the cholera, and other disorders.

Mr. T. Forster, a respectable writer on natural science, author of "Researches about Atmospherical Phenomena," &c., published in 1829 a work on the "Atmospherical Causes of Epidemic Diseases," in which he maintains that the most unhealthy periods are those during which some great comet has been seen; that the appearance of these bodies has been accompanied by earthquakes, eruptions of volcanoes, and atmospheric commotions; and that no comet has been seen during seasons of healthiness. For example, in the year 1665 a comet made its appearance, and soon after its disappearance, the city of London was ravaged by the plague. In 1680 one of the most splendid comets which have been observed in modern times made its appearance. The atmospheric effect produced by its influence, according to Mr. Forster, was "a cold winter, followed by a dry and hot summer," and "meteors in Germany." As the influence of comets on our globe and its atmosphere (if such an influence exist) must have a respect to the whole earth, and not merely to any particular por-

'ion of it, we might ask, in reference to the first example, why did not the comet of 1665 produce a similar effect in Amsterdam, Vienna, Paris and Madrid, and in the principal cities of Asia, Africa, and America? But of such effects we never had the least intimation. In respect to the second example, we are warranted to inquire, whether the cold winter was followed by a hot summer in every other climate of the earth? whether meteors were as common in other countries as in Germany? and whether the comet produced opposite effects, at one time congealing the pools and rivers, and at another scorching the earth with heat? If such questions cannot be satisfactorily answered, we are not warranted in attributing such effects to the influence of comets.

We err egregiously, in this as well as in many other respects, when we infer, from two contemporaneous events, that the one is either the sign or the *cause* of the other. It is on a principle of this kind that some persons are led to attribute the events to which we have alluded to the influence of comets. Because an inundation, a war, a political convulsion, or a volcanic eruption has taken place at the time of the approach of a comet to this part of our system, therefore they conclude that there must be a certain connexion between such events, and that the one is the cause, and the other the effect; while the two events, in point of fact, may not have the slightest relation to each other, except their casual occurrence at the same period. We might, on the same grounds, infer that the rising of the star *Sirius* along with the sun, which announced to the Egyptians the rise of the Nile, was the *cause* of the annual overflowing of that river. Before we can identify any event with the influence of a comet, we must not confine our views to an event or two in our immediate neighbourhood, but must endeavour to ascertain whether similar events or phenomena have happened *on every part of the earth* at the same period. As comets, either large or small, either visible to the naked eye or through a telescope, make their appearance at an average almost every year, and as epidemics, political commotions, earthquakes, hurricanes and similar events are always to be found occurring in some particular portions of the globe, we should never be at a loss for a physical cause to account for every thing that happens here below, if comets are to be supposed to have such an influence over terrestrial affairs. Whatever takes place in any country of an uncommon nature might then be attributed to a comet which is either approaching the centre of our system or receding from it.

It is remarkable that the announcement of a comet has generally been received with melancholy anticipations, and the effects attributed to its influence have uniformly been of a calamitous nature. But why should it not be the precursor of prosperous events—of peace, plenty, social tranquillity, and genial seasons—as well as of wars, famines, revolutions, cold winters, and parched summers? It seems something like a reflection on the general benevolence of the Deity to imagine that he has created such a vast number of bodies, and directed their course through every part of the planetary regions, chiefly for the purpose of "shaking from their horrid hair" wars, famines, and pestilence; for if they produce such effects upon the earth, we might with equal reason believe that they produce similar effects on the other planets of our system as they pass along in their course towards the sun; and this would lead us to infer that the inhabitants of all the planetary orbs are liable to the same disasters and calamities as the inhabitants of the earth, a position which seems scarcely consistent with the boundless benevolence of the Divine mind.

But although I do not admit the conclusions and the cometary influences to which I have alluded, I am far from asserting that comets have no influence whatever over our globe or its surrounding atmosphere. The universe is one great whole, and all its parts, however remote, must be supposed to have a certain relation to one another; and they may produce an influence, however small and imperceptible, on each other at the greatest distances. The remotest star perceptible to the eye may produce a certain physical influence on our globe, though so small and insensible as to be beyond the limits of the nicest calculation; and therefore comets which sometimes approach pretty near the earth may produce a certain sensible effect upon our globe, particularly should a portion of their immense tails at any time sweep along the higher regions of our atmosphere. But what special influence or effects they may produce on the physical economy of our terrestrial system it is impossible for us in the mean time distinctly to ascertain, from our ignorance of the constitution of those mysterious bodies, and of the substances of which they are composed. While too much has doubtless been attributed to the influence of comets, it would be verging to an opposite extreme to maintain that they can produce no effect at all on our earth and atmosphere. We know that certain celestial bodies produce a powerful influence on our globe. The moon, in conjunction with the solar influence, rules the ocean and perpetuates the regular returns of ebb and flow. Its light not only cheers our winter nights, but produces a variety of other influences both on the human constitu-

tion, the atmosphere, and on the productions of the earth; and there may be many effects produced by its agency with which we are as yet unacquainted.* The sun not only diffuses light over every region of the earth for the purpose of vision, but rays or emanations invisible to our sight proceed from his body, which promote evaporation, the growth of vegetables, and the various degrees of temperature which prevail throughout the globe. These emanations are likewise found to produce certain chemical effects, to dissolve certain combinations of oxygen, and to give polarity to the magnetic needle; and many other effects of which we are ignorant may afterwards be found to proceed from those invisible irradiations. The larger planets, Jupiter and Saturn, and those which are nearest to us, as Venus and Mars, may likewise produce certain effects on our globe, both in virtue of their attractive power and of the peculiar nature of the reflected rays they transmit to the regions we occupy.

We cannot therefore but conclude, that comets may exert a peculiar influence on our terrestrial system in addition to that of other celestial bodies, and different from it, particularly those whose bulk and masses are considerable, and which approach nearest to the earth. Their light, whether native or reflected, appears to be peculiar, and the margin of their immense tails may occasionally graze our atmosphere when we are not aware of it, and may produce a peculiar effect different from that produced by the other bodies of our system; but what that special effect is has not hitherto been determined; for the mere coincidences of certain events with the appearance of comets cannot be supposed to be owing to their peculiar influence, unless such events are found uniformly to happen on the apparition of a comet, and that too throughout a great portion of the earth. This subject is worthy of some attention; and perhaps future observers by more accurate observations than have hitherto been made, may throw some light on an influence which on the one hand has been perhaps too rashly set aside, and on the other carried to a pitch of extravagance beyond the line of sober reason and observation.

Let it not be supposed that, in admitting that comets may have an influence on our globe, I mean to give the least countenance to foolish superstitions, or to the absurdities of astrology, since all that I would be disposed to admit in the present case is purely a *physical* influence; an influence which may exist, although we have not yet been able to discriminate its specific effects. The most eminent philosophers have been disposed to admit such an influence. Sir Isaac Newton supposed that "the atmospheres and tails of comets may supply the planets with moisture, which is continually wasting by the growing of vegetables out of water and turning into earth;" and that from the same source may be derived "the purest part of our air, which is requisite for the existence of living beings." These opinions, indeed, cannot be proved, and they are evidently untenable; but they show that that great philosopher admitted the influence of comets. M. Arago, although he scouts the vulgar idea of comets being the cause of most calamitous events, yet he admits that, "not only cometary matter may fall into our atmosphere, but that this phenomenon is of a nature to occur frequently, and may possibly produce those epidemic diseases which have been attributed to it."

A variety of questions has been started respecting cometary action and influence, besides those to which we have now alluded. It has been a question whether we ought to have recourse to the action of a comet *to account for the rigor of the climate of North America?* It is found that in the northern regions of America, the climate in the same latitude is much colder than in Europe. To account for this, Dr. Halley supposed that a comet had formerly struck the earth obliquely, and changed the position of its axis of rotation. In consequence of that event, the North Pole, which had been originally very near to

* It is stated by Mr. Martin, in his "Description of the Western Isles," that "peat dug in the increase of the moon continues moist and never burns clear, while the contrary is observed of that cut in the decrease; and that earthen dykes thrown up in the latter season are alone found to possess stability." It is also stated as a fact, that if an animal fresh killed be exposed to the moon's rays, it will in a few hours become putrid, while another animal, only a few feet distant, protected from their influence, will not be in the least affected; that fruits exposed to moonlight have been known to ripen much more readily; that plants bleached in the dark recover their colour from the beams of a full moon; and that in South America, trees cut at the full moon split almost immediately, as if torn asunder by great external force. Fish are said to be rapidly decomposed in the West Indies when taken by moonlight."—*Webb's MS. Treatise on Comets.* Unless such alleged facts can be *disproved*, we must admit that the Moon may have a certain influence in such cases, though we may be unable to explain the mode by which it is effected. In Carne's "Letters from the East," we are told, that "the effect of the moonlight on the eyes in eastern countries is singularly injurious. The natives tell you always to cover your eyes when you sleep in the open air. The moon here really strikes or affects the sight, when you sleep exposed to it, much more than the sun; a fact of which I had a very unpleasant proof one night, and took care to guard against it afterwards. Indeed, the sight of a person who should sleep with his face exposed to the moon at night would soon be utterly impaired or destroyed." This circumstance strikingly illustrates the expression of the Psalmist—"The sun shall not strike or smite thee by day, *nor the moon by night.*"

Hudson's Bay, was changed to a more easterly position; but the countries which it abandoned had been so long a time and so deeply frozen, that vestiges still remain of its ancient polar rigor, and that a long series of years would be required for the solar action to impart to the northern parts of the new continent the climate of their present geographical position. But we have no proof that a comet has ever struck the earth, or that its concussion would have the effect to change the direction of the terrestrial axis. Besides, it is well known that the Asiatic coast is equally cold in the same latitudes as the Atlantic shores of North America.

It has likewise been a subject of inquiry, *whether the depression of the soil of a great part of Asia* has been produced by the shock of a comet; and *whether Siberia ever experienced a sudden change* by a similar event? This latter inquiry has been suggested by the circumstance of the bones of elephants, rhinoceroses, and other animals peculiar to the torrid zone, having been found embedded in the strata of that country, which has led to the supposition that Siberia was, at some remote period, comprised within the tropics. But there is no proof, nor even probability, that the action of a comet was concerned in either case. It has also been supposed that the small planets, Vesta, Juno, Ceres, and Pallas, the supposed fragments of a large planet, may have been broken to pieces by the shock of a comet. The circumstance that two of these planets, Ceres and Pallas, are encompassed with an atmosphere of great density and elevation, has been brought forward as a presumptive proof of the reality of such a concussion, and that the cometary atmosphere, not being liable to destruction by the percussion, was imparted to these planets. But when we consider the very small density of comets, it appears not at all probable that even a direct concussion from such a body would have produced such an effect, although it might have caused a considerable derangement of the physical constitution of the planet. Besides, this hypothesis does not account for the remarkable fact that Vesta and Juno exhibit no traces of an atmosphere which, in consistency with the supposition, ought to have been imparted to them by the comet, as well as to Ceres and Pallas. On the whole, we have no direct or satisfactory proofs that comets have ever come in direct contact with our globe, or that they have produced any considerable derangements throughout the planetary system; and whatever specific influence they may produce on our earth and atmosphere must be deduced from future observations.

### ON THE INHABITABILITY OF COMETS.

Some philosophers have been disposed to doubt whether the constitution of comets be at all fitted for the abode of rational beings, especially when we take into consideration the extremes of heat and cold to which they would be subjected in their long and extensive career. Mr. Whiston supposed that on this account they could not be the abodes of happiness, and therefore was led to believe that they were the places of punishment for the wicked, who were alternately wheeled into regions of intolerable heat, and afterwards exposed to all the rigors of the most intense cold. But when we consider the boundless beneficence of the Divine Being, and that "his tender mercies are displayed over all his works," we cannot for a moment suppose that so vast a number of these bodies would be created for such an end. The celebrated Lambert, on the other hand, considers comets as constituting some of the most splendid regions of the universe, and that their inhabitants are permitted to contemplate the scene of nature on a scale of grandeur far surpassing that which is presented to the population of the planets.

Many of the comets which exhibit no signs of a nucleus appear to be composed of very light, transparent, and gaseous substances; and therefore it is not very probable that such bodies are inhabited. Comets in this state are supposed, by some philosophers, to be only approaching to a state of consolidation. But as to those which have a large and solid nucleus, there appears to be no physical impossibility, nor even improbability, of their being the abodes of sentient and intellectual beings, as well as the other moving bodies of our system. The extremes of heat and cold to which comets are supposed to be subjected forms the principal argument against the opinion that these bodies are inhabited. But in reply to such an objection it may be stated, that we have no proof that heat or cold depend altogether on the distance of a body from the sun, but most probably on certain circumstances connected with the constitution of the body itself. Besides, it is a fact, that in the heating of bodies there is a certain point, beyond which their temperature can never be raised; as, for instance, in the case of water, which cannot be heated beyond the point of 212° of Fahrenheit's thermometer; and therefore the surface of a comet may have a certain point beyond which its temperature can never be elevated, even at its nearest approach to the sun. "When, by any means," says Mr. Milne, "the density of bodies is made to change by a process, whether of rarefaction, on the one hand, or of condensa-

tion, on the other, they are always found to undergo a corresponding diminution or increase of temperature. When, therefore, in the approach of a comet to the sun, all the parts of its nebulous envelope and tail which in the remoter regions of its course had been gathered close about the head, become expanded and attenuated, a very large proportion of the solar heat, which would otherwise have passed into the nucleus, and contributed to raise its temperature to a certain point, is carried off by the envelope and tail, in order to preserve an equilibrium among the several parts." Mr. Milne proves that, if we assume that the nebulous matter is elevated about 30 times its former height, the diminution of density corresponding with the increase of volume will amount to 27,000, and that a quantity of caloric will be abstracted corresponding to 1,215,000° of Fahrenheit. He further shows that, "when the comet retires towards its aphelion, where the heat of the sun becomes so much weakened on account of the distance, the condensation of the nebulous matter forming the tail and envelope serves not only to furnish the nucleus with continual supplies from the heat acquired at the perihelion, but even to render the warming influence of the solar rays much more efficacious than at a less remote part of the comet's orbit."*

The extremes of heat and cold, therefore, in comets may not be so great as at first view we should be apt to imagine, and their constitution may be such as is not incompatible with the idea that they are inhabited by animated beings. We are not, however, to suppose that the constitution of beings like man would be adapted to the circumstances and changes to which comets are subjected, nor is such a supposition necessary in order to prove their inhabitability. For in the case of all worlds and beings, we must necessarily admit that the Creator has adapted the constitution of the inhabitants to the nature of the habitation. We find a striking variety in this respect in the constitution of the numerous orders of sentient beings that people the globe on which we live; and a similar variety doubtless exists in the peculiar constitutions of the inhabitants of the different planets, and of all the worlds in the universe. For any thing we can prove to the contrary, some of the comets may be the abodes of greater happiness than is to be found in our sublunary world, and may be peopled with intelligences of a higher order than the race of man. In consequence of the extensive regions through which they move, and the variety of objects which will successively burst upon their view, their prospects of the scenes of the universe will be far more diversified and expansive than those of the inhabitants of the planets.

At one period they will behold the stupendous globe of the sun filling a great portion of their celestial hemisphere, and be enabled to contemplate the august and splendid operations going on upon its surface and in its luminous atmosphere, a spectacle of grandeur which must be beyond conception sublime and overpowering. At another period they will be enabled to survey, at no great distance, the phenomenon and economy of some of the planetary worlds. The comet of 1744 passed within 180 terrestrial diameters, or 1,440,000 miles of the earth's surface, at which time its inhabitants (if any) would enjoy an interesting view of our earth and moon, with their diversified motions, and the general aspect of their surfaces. The same comet twice traversed the system of Jupiter's satellites, when the magnificent globe of Jupiter would appear at least 300 times larger than the moon appears to us, and when its satellites would likewise present a very large and splendid appearance. From such a position, even with eyes such as ours, assisted by telescopes, all the diversity of surface of this huge globe, as presented in its diurnal rotation, with the changes of its belts, and the peculiar scenery of its satellites, would be distinctly perceived. Above all, the system of Saturn will present a most magnificent spectacle to the inhabitants of a comet when it passes through the regions in its immediate vicinity. Its expansive rings, filling a considerable portion of the visible firmament, their rapid rotation round the planet, the vast globe of Saturn itself, and the numerous satellites which accompany it, in all their different phases and rapid motions, will present a scene at once diversified and sublime. To the inhabitants of comets, many vast bodies within the range of our system may be visible, which we have never yet discovered, and which may never be perceptible from the region we occupy. Traversing vast regions of space far beyond the orbit of Uranus, and perhaps approaching to the nearest stars, worlds may be presented to their view of which we have no conception, and the planets which revolve around other suns may be distinguishable in the remoter parts of their course. Enjoying such diversified and extensive prospects of the operations of Omnipotence, the intellectual beings who reside on those bodies will acquire more expansive views than the inhabitants of the earth of the vast scene of nature and of the perfections of that Allwise and Almighty Being whose power brought into existence,

* Milne, Prize Essay on Comets, Part IV.

as whose incessant energy sustains in being, all the worlds in the universe.

The number of comets is supposed by some astronomers to amount to several millions; and if so, they must frequently pass near each other in their long eccentric courses, and consequently the beings connected with them will have their prospects of other worlds wonderfully diversified and continually expanding. It is likewise supposed that comets sometimes extend their excursions to other suns. On this point M. Lambert has the following remarks: "I shall suppose that a globe in our system begins to describe a parabola. If this curve closes and returns into itself, the globe will remain with us, and acquire a periodical motion round the sun. If, on the contrary, it extends its limits, so as to become a hyperbola, the globe will recede more and more from the sun, and leave us, never to return. Were we to pursue the fugitive in idea, we should see it perhaps at the end of some thousands of years flit along the frontiers of our system and dive into a neighbouring world. The central body of this world would then exercise its attraction over the new visitor, and give a curvature to his orbit. From that moment one of two things would happen. Either its path would change into an ellipse, in which case its travels would be at an end, and it would proceed to make regular revolutions round the dominant star of that system; or, perhaps, after passing its perihelion, it would again resume its hyperbolic progress, and approaching the asymptote, withdraw in a straight line, and proceed to visit other worlds. Thus we can conceive comets which, being attached to no particular system, are in common to all, and which, roaming from one world to another, make the tour of the universe. I ask why, in the infinite variety which the Creator has introduced into his works, such globes should not have a place? Their destination may embrace the wisest purposes, concerning which we may be allowed to speculate."

This celebrated philosopher concludes his remarks on comets with the following reflections, which, although somewhat fanciful, may not be unworthy of the attention of the reader:

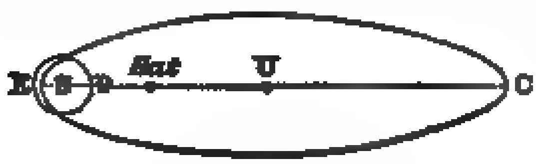
"I love to figure to myself those travelling globes, peopled with astronomers, who are stationed there for the express purpose of contemplating nature on a large, as we contemplate it on a small scale. Their movable observatory cruising from sun to sun, carries them in succession through every different point of view, places them in a situation to survey all, to determine the position and motion of each star, to measure the orbits of the planets and comets which revolve round them, to observe how particular are resolved into general laws, in one word, to get acquainted with the whole as well as the detail. We may suppose that their year is measured by the length of their route from one sun to another. Winter falls in the middle of their journey; each passage of a perihelion is the return of summer; each introduction to a new world is the revival of spring; and the period of quitting it is the beginning of their autumn. The place of their abode is accommodated to all their distances from the fixed stars, and the different degrees of their heat make the fruits and vegetables designed for their use blossom and ripen. Happy intelligences, how excellent must be the frame of your nature! Myriads of ages pass away with you like so many days with the inhabitants of the earth. Our largest measurements are your infinitely small quantities; our millions the elements of your arithmetic; we breathe but a moment; our lot is error and death, yours science and immortality. All this is agreeable to the analogy of the works of creation. The frame of the universe furnishes matter of contemplation as a whole as well as in each of its parts. There is not a point that does not merit our observation; this magnificent fabric is portioned out in detached parts to created beings; but it is in the unity of the whole that sovereign perfection shines; and can we suppose that this whole has no observers? The imagination, indeed, after so sublime a flight, may be astonished at its own temerity; but, in short, here the cause is proportioned to the effect, and there is nothing great or small in immensity and eternity."

### ON THE MOTIONS AND ORBITS OF COMETS.

When a comet comes within the limits of our view, its apparent motion is from east to west, and it generally appears to rise and set like most of the other heavenly bodies. This motion, however, like that of the diurnal motion of the sun and planets, is only *apparent*, and arises from the rotation of the earth upon its axis. Besides this apparent motion, it has a *real* and proper motion of its own, by which it is continually shifting its place in the heavens, in conformity to the nature of the orbit in which it moves. "The proper course of a comet may be found by observing every night its distance from two fixed stars whose longitudes and latitudes are known; or by finding its altitude when in the same azimuth with two known fixed stars; or by noting four fixed stars in the point of intersection of the two lines connecting which the comet is found. If the places of the comet, as thus observed every night, be marked on the celestial globe, a line drawn through them will represent the comet's path among the stars; a

great circle drawn through three distant places will nearly show the way it has to go. If it be continued till it intersect the ecliptic, it will show nearly the place of the node and the inclination of the orbit to the ecliptic."* There is, however, a practical difficulty which

Fig. 82.




perplexes the observer in attempting to ascertain the true form of a cometary orbit. A comet remains so short a time in sight, and describes so small a part of its course within our view, that, from observation alone, without the assistance of hypothesis, we should not be able to determine the nature of its path. The only part of the course of a comet that can ever be visible is a portion throughout which the ellipse, the parabola, and hyperbola, so closely resemble each other that no observations can be obtained with sufficient accuracy to enable us to distinguish them. The hypothesis most conformable to analogy is, that the comet moves in an ellipse, having the sun in one of the foci, and that the *radius vector* from the sun to the comet describes areas proportional to the times, according to the law observed by the planets. If it be supposed that the comet describes an ellipse or a parabola, in conformity to the laws of Kepler, then from three geocentric places, known by observation, the orbit may be determined.

Fig. 83.

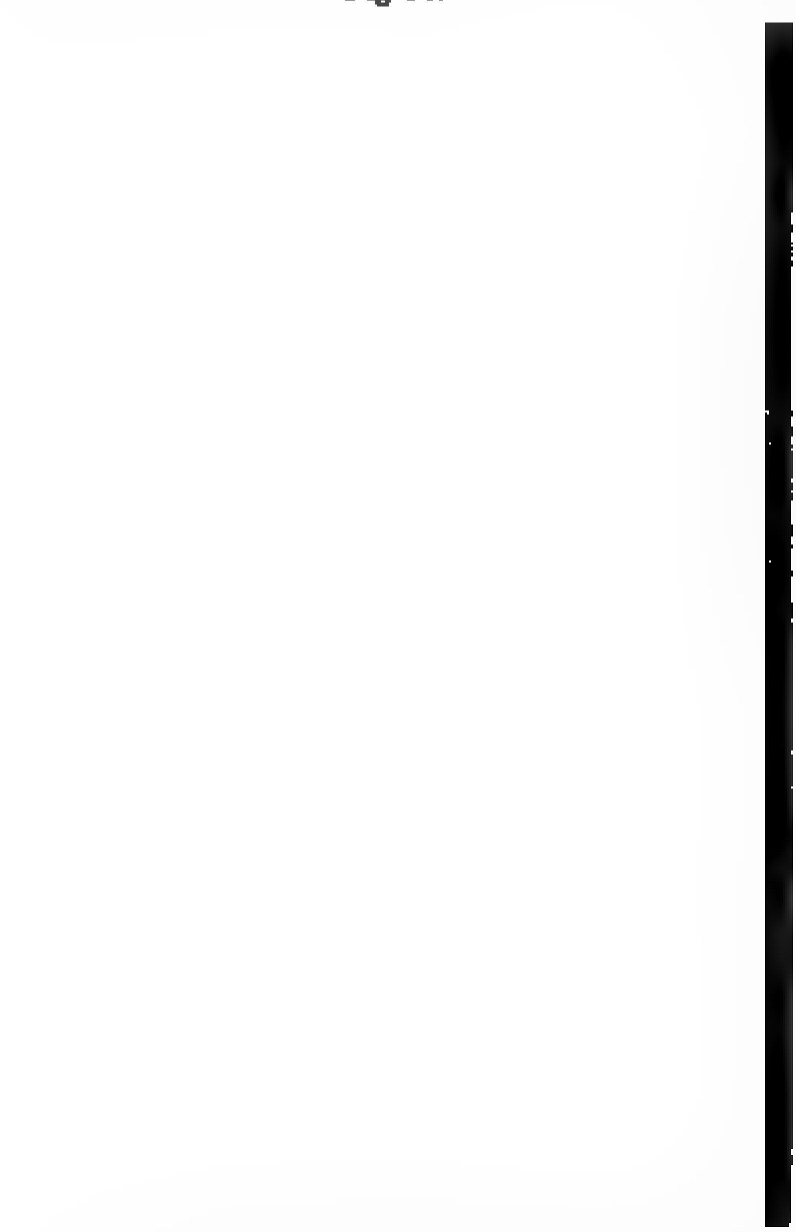
The orbits of the planets, although elliptical, approach very nearly to circles; but those of comets are extremely eccentric, and form very elongated ellipses. The orbit of Halley's comet is four times longer than it is broad, and the orbits of those comets whose periodical revolution exceeds a hundred or a thousand years must be still more elongated and eccentric. Fig. 82 represents the orbit of Halley's comet nearly in its exact proportions. *E C* represents the length of the ellipsis in which it performs its revolution; *E D*, the orbit of the earth, somewhat larger than it ought to be in proportion to the comet's orbit; *S*, the sun in one of the foci of the ellipse; *Sat.*, the proportional distance of the planet Saturn from the sun; and *U*, the proportional distance of Uranus. The orbit of this comet extends to nearly double the distance of Uranus:

Fig. 83 represents so much of the trajectory of the comet of 1680 as it passed through while visible to the inhabitants of our globe, as delineated in Newton's "*Principia.*" It shows also the tail as it appeared on the days mentioned in the figure. Like that of other comets, it increased in length and brightness as it came nearer to the sun, and grew shorter and fainter as it went further from that luminary and from the earth, till the comet was too distant to be visible. This comet was observed in the morning from November 4 to November 25, 1680, in its descent towards its perihelion at *P*; and its positions on the

* Dr O. Gregory's "Treatise on Astronomy."

17th, 21st, and 25th of that month are here exhibited. It appears to have passed its perihelion sometime between the 25th of November and the 12th of December. Its positions on the 12th, and 21st, and 29th of December, and on the 5th and 25th of January, 1681, after returning from its perihelion, as seen in the evening, are marked in the figure. The orbit of this comet must be extremely elongated, as its return is not expected for more than 400 years to come.

Fig 84.



*Representation of the orbit of the Comet of* 1832, *with the relative position of the orbit of the Earth.*

Fig. 84, taken from Arago's "Scientific Notices of Comets," exhibits a representation of the orbit of Biela's comet, with the relative position of the orbit to the earth. It shows both the space and the position it occupies in the solar system, and the points where its orbit intersects all the planetary orbits through which it passes. It exhibits its course at its return in November, 1832, and the path it describes till its subsequent return in 1839. From this figure it is seen that its perihelion lies between the orbits of the earth and Venus, and that its aphelion extends beyond the orbit of Jupiter. It would arrive at that point which is most distant from the earth, in the spring of 1836, and will probably return to it in January, 1843. The nearest approach to the earth of this comet was 51 millions of miles; its nearest approach to the sun, 83 millions; its mean distance from the sun, or half the longest axis of its orbit, 337 millions; and it is 507 millions of miles nearer the sun in its perihelion than in its aphelion. To be able to calculate and predict the future positions and appearances of such a body evinces an accuracy of observation, and a degree of perfection of astronomical *calculus*, which may justly challenge admiration, and which should lead those who are unacquainted with the minutiæ of astronomy to receive with confidence the results which have been deduced by those who have devoted themselves to celestial investigations.

#### SUPPOSED NUMBER OF COMETS.

It is laid down as a principle by M. Lambert, that as the world is the expression of the perfections of God, we must believe that all the heavenly bodies are inhabited, and "*that universal space is replenished with as many globes as it can contain*," so as to move with freedom and security within the circumference of the universe. Hence he infers, that the most perfect plan of our system will be that into which enters the greatest number of orbits, all separated from one another, and which in no one point intersects the other; and that the orbits of comets correspond to this end better than those of the planets, as an immensely greater number of elliptic or cometary orbits can be introduced into the system than of those which are circular. On the ground of the number of comets which have hitherto been observed, and on certain mathematical considerations, he instituted calculations which led to the conclusion that "at least five hundred millions of comets" might be contained within the limits of the solar system. On this point, M. Arago reasons in the following manner: — The number of comets really known, whose peri-

helion distance is less than the radius of the orbit of Mercury, amounts to thirty. This radius, and that of the orbit of Uranus, are in the ratio of 1 to 49; and the volumes of two spheres are to each other as the cubes of their radii. If, therefore, we adopt the hypothesis of the equal distribution of comets in all the regions of our system, and calculate the number of those luminaries whose perihelions are included in a sphere whose radius is the distance of Uranus from the sun, the following proposition would be supplied to us:—As the cube of 1 : to the cube of 49 : : so is 30 : to the number of comets sought;—or thus, $1^3 : 49^3 : : 30$; or, 1 : 117,649 : : 30 : 3,529,470. Thus within the orbit of Uranus, the solar system should contain more than three millions and a half of comets; or, we should rather find the double of that the true number, when we consider that in this calculation the term which represents the number of comets contained within the sphere of Mercury is certainly much too small, and that it ought to be conceded that the light of day, our clouded skies, and a too southerly declination, removes from our sight not fewer than every alternate one of these bodies. Taking these circumstances into consideration, there should, on the same hypothesis, be seven millions of comets.

The actual number of comets, however, which have been observed since the commencement of the Christian era, does not amount to above seven or eight hundred; but when we consider that in the earlier ages of astronomy, and likewise in more recent periods before the invention of the telescope, only large and conspicuous comets were noticed, and that the greater number, in all probability, had their visible courses in the southern regions of the heavens, and of whose appearance we have no records, it will easily be conceived that their actual number must amount to at least many thousands. Since particular attention has been directed to the astronomy of comets, and since the number of observers have increased, scarcely a year has passed without the observance of one or two of these bodies, and sometimes even two or three have appeared at once. In the year 1825, no less than *four* comets made their appearance within the space of three months. The first of these was discovered by M. Gambart, at Marseilles, on May 9, in the head of *Cassiopeia*; the second by M. Valtz, at Nismes, on July 13, in *Taurus*; the third by M. Pono, at Florence, on August 9, in *Auriga*; the fourth, or Encke's comet, about the months of July or August. But it is evident that multitudes must escape all observation, by reason of their paths traversing only that portion of the heavens which is visible in the daytime.

The number of comets whose paths have been particularly observed during their visible course is about 137. Of these, sixty-nine moved in a *direct* course, or according to the order of the signs, as the planets do, and sixty-eight in a retrograde direction. As to the *distances of their perihelions* from the sun and the earth, thirty were found to have their perihelions between the orbit of Mercury and the sun; forty-four, between the orbits of Mercury and Venus; thirty-four, between the orbits of Venus and the earth; twenty-three, between the orbits of the Earth and Mars; six, between the orbits of Mars and Jupiter. Beyond the orbit of Jupiter no comets have been perceived; and it is seldom they can be seen beyond the orbit of Mars. As to *the inclination of their orbits*, nine comets have been observed whose orbits incline to the ecliptic from 0° to 10°; thirteen, from 10° to 20°; ten, from 20° to 30°; seventeen, from 30° to 40°; fourteen, from 40° to 50°; twenty three, from 50° to 60°; seventeen, from 60° to 70; nineteen, from 70° to 80°; fifteen, from 80° to 90°. It appears, then, that these 137 comets had their orbits inclined in almost every degree to the ecliptic; and it is probable that this is the case with all the other comets which belong to the system.

Although comets generally emit an obscure light, yet some have been seen whose splendour was so great as to be visible in daylight, even at noon, and while the sun was shining in all its brightness. Such, it is said, were the comets which appeared in 1402 and 1532, and that which appeared a little before the assassination of Cæsar, and which was supposed, after that event happened, to have been an omen or prelude of his death. It has likewise been stated, that comets have appeared of such a magnitude as to have eclipsed the sun. Seneca relates that such a coincidence happened sixty years before Christ, when a large comet was actually observed very near the sun.* The same author relates that a comet which appeared in the time of the Emperor Nero was not inferior in apparent magnitude to the sun himself;† and the comet which Hevelius observed in the year 1652 did not seem to be less than the moon, though it was deficient in splendour.

Comets traverse all parts of the heavens and, as already noticed, their orbits have every possible inclination to the plane of the ecliptic. They are, however, governed in their motions by the same physical laws which regulate the motions of the planets. Their periodical times are to the periodical times of the planets, in the sesquiplicate ratio of their principal axes. Comets, therefore, being for

* Sir John Herschel's Astronomy.
† Dr. O. Gregory's Astronomy.

the most part beyond the planetary regions, and on that account describing orbits with much larger major axes than the planets, revolve more slowly. Thus, if the major axis of a comet's orbit be four times as long as that of the orbit of Uranus, the time of the comet's period would be to that of the planet as 8 : 1; its periodic time would therefore be nearly 672 years; that is, $8 \times 84$ — the period of Uranus $= 672$. Although comets move with great rapidity when near their perihelion, yet in the remote parts of their course their motion must be proportionally slow.

The motions of comets when approaching the sun are in certain cases extremely rapid. The comet which was observed by Regiomontanus, in 1472, was said to have passed through 40 degrees of a great circle in twenty-four hours. Brydone, in his "Tour through Sicily," relates that he observed a comet at Palermo, in June and July, 1770, which moved through 50 degrees of a great circle in twenty-four hours. At midnight, on the 30th of June, it passed the zenith of Palermo (latitude 38° 10′,) and the next day, July 1, at 40 minutes past eight, P. M., it passed 4 degrees to the east of the polar star. He remarks that, "supposing it at the distance of the sun, at this rate of travelling, it would go round the earth's orbit in less than a week, which makes about eighty millions of miles a day,—a motion that vastly surpasses all human comprehension. And as this motion continues to be greatly accelerated, what must it be when the comet approaches still nearer to the body of the sun!" It is probable, however, that the comet was considerably nearer the earth than the distance of the sun; but still the velocity with which it was impelled must have been amazingly great.

Such is a brief summary of the most remarkable facts, interesting to the general readers, which have been ascertained in relation to comets. It is to be hoped that, in the progress of astronomical discovery, some additional light will be thrown on the nature and the destination of those mysterious bodies, whose number appears so far to surpass that of the primary and secondary planets of our system. It was long ago predicted by Seneca, a Roman philosopher who lived in the first century of the Christian era, "that the time will come when the nature of comets and their magnitude will be demonstrated, and the courses they take so different from those of the planets; and that posterity will wonder that the preceding ages should be ignorant in matters so plain and easy to be known." In order that this prediction may be fully realized, it is requisite that we should become acquainted with all the observations that have hitherto been made, and the facts in relation to these bodies which have been ascertained; that we should compare the various observations with each other, and attend to the minutest circumstances and phenomena connected with comets; that numerous observers should be appointed to survey different portions of the firmament, both in the northern and southern hemispheres, that no comet that comes within the limits of our vision may pass unobserved; and that when a comet of large size approaches near the centre of our system, every minute particular in reference to its motions, and the changes which takes place in its nucleus, envelope, and tail, be carefully observed and delineated by accurate representations.

Whatever opinions we may adopt as to the physical constitution of comets, we must admit that they serve some grand and important purpose in the economy of the universe; for we cannot suppose that the Almighty has created such an immense number of bodies, and set them in rapid motion according to established laws, without an end worthy of his perfections, and, on the whole, beneficial to the inhabitants of the system through which they move.

They display the *wisdom* of their Creator *in the arrangements of their orbits and motions*. As we have every reason to conclude that at least thousands of those bodies traverse the solar system in all directions, and are certain that their orbits are inclined in every possible degree to one another, and to the orbit of the earth, so we find that they have been so admirably arranged by Divine Intelligence, that no one of them interferes with another, or with the courses of the planets, so as to produce concussion or disorder. The orbits of some comets indeed are found to approach very near, and even to cross the orbit of the earth and the orbits of several other planets, and consequently, there is a *possibility* that a comet might come into concussion with our globe; and this consideration shows us that that we are dependent for our present security and comforts on the wise arrangements of the Almighty, in securing perfect harmony and order amidst apparent danger and confusion. But we have no evidence that such a catastrophe has ever happened, either in the case of the earth or of any of the other planets, or that one comet has ever impinged upon another. Believing that every object and event in the universe is arranged and directed by an Omnipotent Contriver, we must admit that when the Almighty formed the wondrous plan of creation, "forseeing the end from the beginning," he arranged the periods and the velocities of comets in such a manner that, although occasionally crossing the planetary orbits, they should not pass these orbits at the

time when the planets were in their immediate vicinity. And should such an event ever occur, we may rest assured that it is in perfect accordance with the plan and the will of Omnipotence, and that it is, on the whole, subservient to the happiness and order of the intelligent universe, and the ends intended by the Divine government. If there are thousands and perhaps millions of comets of all descriptions traversing every part of the planetary regions, in orbits of every degree of inclination, of extent, and of eccentricity, we are sure that none but a Being of infinite power and intelligence could have arranged such a vast and complicated system, so as to have prevented numerous interferences and disasters, and to make the whole move onward for ages in perfect harmony.

The system of comets likewise presents to us a display of *the omnipotence and grandeur of the Deity*. The number of these celestial visitors, the vast magnitude of their tails, envelopes, and nuclei, and the amazing velocity with which they wheel their courses through the ethereal regions, exhibit before us objects of astonishing grandeur, and evince the Almighty power of Him who at first impelled them in their rapid career. The diameter of the nucleus of the comet of 1807 was estimated by Schroeter at 4600 miles, and that of its coma 120,000 miles. Besides its principal tail, it shot forth coruscations to the extent of four millions, six hundred thousand miles. The nucleus of the comet of 1811 was, according to the same observer, 50,000 miles in diameter, its coma or envelope 947,000 miles, and its tail or train of light, sixty millions of miles in length, or more than half the distance between the earth and the sun. Let us conceive such a body, like the comet of 1680, traversing the immense spaces of creation with the velocity of ten hundred thousand miles an hour, and drawing after it a luminous train, a hundred millions of miles in length, approaching at one time so near the sun that his circumference would appear to fill the greater part of the firmament, and then rushing back through the depths of immeasurable space, thousands of millions of miles beyond the orbit of Uranus, and displaying its majestic train to the other planetary worlds of our system—and we have presented to our mental eye an object of peculiar grandeur and magnificence, different from every thing else which the planetary system exhibits, and which displays in an eminent degree the power and magnificence of the Great Creator. Were such a body to sweep along the regions which lie in the immediate vicinity of our globe, at the distance of ten or twelve thousand miles, nothing that we have ever beheld or can well conceive could be compared to the majestic grandeur of the scene, which would overpower the mind both with astonishment and with terror. On the view of such an object, sweeping along with such velocity, we could scarcely refrain from exclaiming, in the language of inspiration, "Great and marvellous are thy works, Lord God Almighty!" What, then, shall we think of thousands of such mysterious orbs winding their flight in every direction, in perfect regularity and order, through the immensity of space! Surely these are the wonderful works of Him who is mighty in operation and perfect in knowledge.

In all the works of the Deity, we must likewise admit that his *goodness* is displayed although we may not be able to trace the mode of its communication; for we may lay it down as an axiom, that wherever wisdom and omnipotence are exhibited throughout the Divine economy, there is also a display of *beneficence*, which appears to be one prominent design of all the works of God. Comets have long been considered as objects of terror, and as omens of impending calamities; but there can be no question that they are as intimately connected with a system of benevolence as are the solar radiations and their benign influence on our globe and on the other planets. It has been conjectured that comets may supply moisture to the planets, and invigorate the vital principle of our atmosphere; that they may recruit the sun with fresh fuel and repair the consumption of his light; or that they may be the agents for dispersing the electric fluid throughout the planetary regions; and although there is little probability that such conjectures are accordant with fact, yet it may be admitted that comets may produce a *physical* influence of a beneficial nature throughout the solar system. But what I conceive to be one of the main designs of the Creator in the formation of such a vast number of splendid bodies is, that they may serve as habitations for myriads of intellectual beings, to whom the Almighty bestows his perfections in a peculiar manner, and on whom he displays the riches of his beneficence. Whatever may be the intention of those comets which are destitute of a nucleus, this, in all probability, is the chief design of those which are large and which are invested with a solid nucleus; and the same arguments which we formerly brought forward to prove that the planets are inhabited might be adduced in proof of the inhabitability of comets. If this position be admitted, then we ought to contemplate the approach of a comet, not as an object of terror or a harbinger of evil, but as a splendid world, of a different construction from ours, conveying millions of happy beings to survey a new region of the Divine empire, to contemplate new scenes of creating power, and to celebrate

in loftier strains the wonders of Omnipotence.* Viewing the comets in this light, what an immense population must be contained within the limits of the solar system, which gives room for the excursions of such a vast number of these bodies! and what an incalculable number of beings of all ranks must people the wide-extended universe!

* The most complete account of the phenomena, &c. of comets I have seen is a treatise on this subject in manuscript, by the Rev. Thomas W. Webb, of *Tretire*, near *Ross*. This treatise contains—1. A copious introduction, embodying a variety of interesting general remarks in relation to this subject. 2. A particular account of the comet of 1807, according to the observations of Sir William Herschel. 3. A description of the same comet from the observations of Dr. Johan. Hieron. Schroeter. 4. An account of the great comet of 1811, according to the observations of Sir W. Herschel. 5. A particular description of the phenomena of the same comet, according to the observations of Schroeter. 6. A description of the second comet of 1811, according to the observations of Sir W. Herschel. These observations, particularly those of Schroeter, contain the most minute descriptions which have hitherto been given of the phenomena of this class of the celestial bodies, and will be found of essential service, not only to amateur observers, but to astronomers of every description. They have been extracted and arranged chiefly from the "Philosophical Transactions," and the works of Schroeter, which were published in the German language. The *Appendix*, or Second Part, which occupies nearly half the volume, comprises a lucid investigation of the following topics—1. Comparison of observations. 2. Examination of hypotheses. 3. Nature, light, and solidity of Comets. 4. Colours of Comets. 5. Brightness of Comets. 6. Divided tails of Comets. 7. Coruscations of Comets. 8. Miscellaneous notices concerning remarkable comets. 9. On the influence of comets. 10. Losses to science containing an account of the disasters which befell Schroeter, Hevelius, &c. 11. Hints to amateur observers. This volume contains 230 quarto pages, besides a great number of copious notes, and forty-six figures of the different appearances of comets. It indicates a very great degree of labour and research, which the astronomer alone will be able fully to appreciate. The author appears to have consulted most of the works which have been published on the subject, in the English, Latin, French, and German languages, besides embodying a number of original observations and remarks. And what is not among the least important features of the work, the author takes every proper opportunity of introducing such moral reflections as the subject naturally suggests, and of directing the contemplations of his readers to Him who sits on the throne of the universe. The observations of Schroeter contained in the preceding pages have been extracted from this volume. It is to be hoped that the worthy author, who is already known to a considerable portion of the scientific world by his communications to periodicals and scientific associations, will soon receive encouragement to lay this work before the public.

# APPENDIX.

## GENERAL APPEARANCE OF THE STARRY HEAVENS AT DIFFERENT PERIODS OF THE YEAR.

The following descriptions are intended to point out to the young observer the principal stars and constellations in the beginning of every alternate month throughout the year, and the particular quarter of the heavens where they may be perceived. The time of observation is supposed to be *nine o'clock in the evening*, except on the 1st of July; but the general aspect of the heavens, and the relative positions of the different stars and constellations, will not be materially different when viewed an hour before or after the time now specified.

### *Aspect of the Heavens on the 1st of January, at nine o'clock in the evening.*

At this time the *Pleiades*, or Seven Stars, are nearly on the meridian, at an elevation of more than 60 degrees above the southern horizon. The bright star *Aldebaran*, or the Bull's Eye, which is of a ruddy hue, appears to the left, in a direction nearly east by south, at the distance of 14°. About 15° east-north-east of Aldebaran is a bright star of the second magnitude, marked *Beta*, or El-nath; from this star to *Zeta*, in the tip of the southern horn of the Bull, is about 8° in a southern direction. This star forms a right angle with Aldebaran and Beta. North of Beta, at the distance of 17°, is the bright star Capella, in the constellation of Auriga, a star of the first magnitude, which appears at a high elevation a few degrees south-east of the zenith. In a direction south-east of Aldebaran and the Pleiades is the splendid constellation of *Orion*. *Bellatrix*, on the west shoulder of Orion, is about 16° south-east of Aldebaran, which is placed in the middle of the line which connects the Pleiades with Bellatrix; these three objects appearing nearly equidistant in a line N.W. and S.E. of each other. Nearly due east from Bellatrix, at the distance of 7½°, is Betelguese, a star of the first magnitude in the east shoulder of

Orion. About 15° south by west of Bellatrix is *Rigel*, a star of the first magnitude in the left foot, and 8½° to the east is *Saiph*, a star of the third magnitude in the right knee of Orion. These four stars in the form of a parallelogram, with the three bright equidistant stars called the *Belt*, form the outlines of this constellation. There is a small triangle of three small stars in the head of Orion which forms a larger triangle with Bellatrix and Betelguese, the two in his shoulders. (See fig. of Orion, p. 30, and Plate I.)

North-east of Betelguese, at the distance of 14°, is the star *Alhena*, or $\gamma$ Geminorum, the principal star in the feet of the Twins; and about 20° N.E., nearly in the same right line from Betelguese, are *Castor* and Pollux, Castor being the uppermost and the brightest, at the distance of only 4½° from Pollux. These and the other stars which lie adjacent to them form the constellation Gemini, one of the signs of the Zodiac. The small stars immediately to the east of Gemini are in the constellation *Cancer*, another zodiacal constellation through which the sun passes in July and August. In this constellation is a nebulous cluster of very small stars, called *Præsepi*, which may be distinguished as a faint cloudy speck by the naked eye. (See page 78.)

Immediately below Orion are the constellations of *Lepus*, or the Hare, and Noah's Dove, which are very near the horizon. South by east of Orion is *Canis Major*, or the Greater Dog, which is distinguished by its principal star *Sirius*, the brightest fixed star in the heavens. It is nearly straight south of Alhena, in the feet of the Twins, at 35° distant, and south by east of Betelguese at the distance of 27°. A line drawn through the three stars in the belt of Orion, and prolonged, meets Sirius at the distance of 23°. About 5½° west of Sirius is *Mirzam*, of the second magnitude, in the foot of the Dog. Nearly due east from Orion, but less elevated above the horizon, is *Canis Minor*, or the Lessor Dog. The centre of this small constellation is situated about 5° north of the equinoctial, and midway between Gemini and Canis Major. It is distinguished by the bright star named *Procyon*, which signifies "before the Dog." About 4° to the north-west is *Gomelza*, a star of the third magnitude. Procyon, at the time supposed, appears nearly due east from Betelguese, at the distance of about 26°. The head of *Hydra* lies immediately to the east of Procyon; but *Alphard*, or *Cor Hydræ*, the principal star of this constellation, is not risen at the time supposed. A little to the north of the eastern point of the compass, and at a very small elevation above the horizon, is *Regulus*, a star of the first magnitude, in the constellation Leo, which is the *fifth* sign, and the sixth constellation of the zodiac.

Turning our faces towards the north-east, *Ursa Major*, or the Great Bear, is the most striking constellation that meets the eye. The two pointers, *Dubhe* and *Merak*, appear uppermost, and point westward to the Pole-star; while the stars forming the tail seem to hang downwards from the square of this constellation. As the night advances, this group of stars rises higher in the heavens, till, about three in the morning, they approach near the zenith. *Ursa Minor*, or the Lesser Bear, is seen *below* the pole, the square of which being a little to the eastward of the meridian. Directly below the Great Bear, at a very small elevation above the horizon, and in a direction N.E. by N., is *Cor Caroli*, a star of the second magnitude, in *Chara*, one of the Grayhounds. North by East of Aldebaran, at the distance of 30°, is the bright star *Capella* in *Auriga*.

Directing our view a little to the west of the meridian, we perceive the constellation *Aries*, which is immediately to the westward of the Pleiades, and nearly at the same altitude. Above 2000 years ago, in the days of Hipparchus, this constellation occupied the first sign in the zodiac, into which the sun entered about the 21st of March; but, as in consequence of the *precession of the equinoxes* the constellations gain about 50″ on the equinox every year, they have now advanced in the ecliptic nearly 31 degrees beyond it, or somewhat more than a whole sign; so that the constellation *Pisces* now occupies the same place in the zodiac that Aries did 2000 years ago, while the *constellation* Aries is now in the *sign* Taurus, Taurus in Gemini, &c., so that Aries, though the *first* sign, is the *second* constellation of the Zodiac. It is situated next east of Pisces, and midway between the *Triangles* and *Musca* on the north, and *Cetus*, or the Whale, on the south. It is distinguished by two bright stars in the head, distant from each other about 4°, the brightest being a little to the east or north-east of the other, being about 25° west of the Pleiades, and 19° south of *Almaack*, in the foot of Andromeda. North by east from Aries is *Musca*, or the Fly, which consists of four or five stars, chiefly of the third and fourth magnitudes, very near to each other. It is situated between the first star of Aries and the Pleiades, but a little higher than either. North by east from the Fly, at the distance of about 15°, and at 20° north by west of the Pleiades, and at a higher elevation, is the head of *Medusa*, the principal star of which is Algol, which regularly varies in its lustre. (See p. 50.) West by north from

Medusa is *Andromeda*, one of the principal stars of which is *Almaack*, at the distance of 12° west by north of Algol. West of Almaack, at the distance of 12°, is *Mirach*, both of them stars of the second magnitude. If the line connecting Almaack and Mirach be prolonged 8° further west or south-west, it will reach *Delta*, a star of the third magnitude in the left breast.

West from Andromeda, and a little to the south, is *Pegasus*, or the Flying Horse, which is distinguished from the other constellations by four bright stars of the second magnitude, forming a square, which is generally termed *the Square of Pegasus*. The northermost star, which is the brightest of three that form a kind of triangle, is *Scheat*, whose N. declination is 26½°. *Markab* is situated 13° south of Scheat, and at the time supposed is nearly due west, and about 22° above the western point of the horizon. These two stars form the *western* side of the square. East from Markab, at the distance of 16½°, is *Algenib*, and 14° north of Algenib is *Alpheratz*; which two stars form the eastern side of the square. Scheat and Alpheratz form the *northern*, and Markab and Algenib the *southern* sides of the square. Alpheratz constitutes a part of the head of Andromeda, but it is also considered as connected with Pegasus. About 26° north of Andromeda is *Cassiopeia*, midway between it and the Pole-star. It passes the meridian nearly in the zenith about the 22d of November. At this time it is between 20° and 30° west of the meridian. (See pp. 18 and 45.) The star *Caph*, in this constellation, along with Alpheratz and Algenib, are situated on the *prime meridian* which passes through the first point of Aries, from which the right ascensions of all the heavenly bodies are measured. The line connecting these stars forms an arc of the *equinoctial colure*, which passes through the vernal equinox, and across which the sun passes on the 21st of March. When we say that the sun, or a star, or a planet is in so many degrees of right ascension, we mean that it is situated, or has moved *eastward* so many degrees from this great circle. North-west of Cassiopeia is *Cepheus*, at the distance of about 25°, the head of which is in the Milky Way, and may be known by three stars of the fourth magnitude in the crown, forming a small acute triangle about 9° from *Alderamin*, a star of the third magnitude in the left shoulder.

Next to Cepheus, on the west, is *Cygnus*, or the Swan; the principal stars of which are distinguished as forming the figure of a large *cross*, the upright piece of which lies along the Milky Way. The most brilliant star in this constellation is *Deneb* Cygni, of the first magnitude, which is at this time in a direction nearly north-west, and 25° above the horizon. West from Deneb, at the distance of 10° or 11°, is *Delta*; and the line prolonged about 15° further leads to the bright star *Vega*, the principal star in *Lyra*, which is then about 6° above the horizon in a direction north-west by north. North by east of Lyra is the head of *Draco*, distinguished by four stars separate from each other by intervals of 3°, 4°, and 5°. The one to the south, or nearest Lyra, is *Etanim*, or $\gamma$ Draconis, which Dr. Bradley fixed upon in his attempt to determine the annual parallax. At this time it is 16° above the horizon, in a direction N. N. W. About 4° to the north of it is *Rastaben*, both of them stars of the second magnitude. Turning our eyes again towards the southern part of the meridian, we behold the head of *Cetus* or the Whale, about 20° S.E. of Aries, and about 24° S. by W. of the Pleiades. It is distinguished by five stars, 4° or 5° asunder, which form a figure resembling a regular *pentagon*. The brightest of these stars, which is the eastermost, and of the second magnitude, is *Menkar*, which makes an equilateral triangle with *Arictis* and the Pleiades, being distant from each about 23½°. About 14° south-west of Menkar is *Mira*, or the Wonderful Star, which is found to vary its apparent size from a star of the second or third, to one of the sixth or seventh magnitude. (See p. 50.) North-west of the head of Cetus, and west of Aries, is the constellation *Pisces*, or the Fishes, one of the signs of the Zodiac, in which there are no remarkable stars, most of them being of the third, fourth, and inferior magnitudes.

Such is the general outline of the heavens as they appear about the beginning of January.

### *General Appearance of the Heavens on the 1st of March, at nine o'clock*, P. M.

At this period of the year, at 9 P. M., several of the constellations which were seen in the beginning of January, have disappeared, such as Pegasus, Pisces, and others. Others, which are still visible, appear in other quarters of the heavens; and some stars and constellations which were then below the horizon have risen to a considerable elevation above it. Orion is now in the south-west quarter of the heavens; the Pleiades, instead of being on the meridian, are due west, at an elevation of 34° above the western point of the horizon; the bright star Sirius is to the west of the meridian, in a direction S. S. W.; Canis Minor and Procyon are a few degrees to the west of the meridian; Castor and Pollux, directly north of Procyon, have likewise passed the meridian; Capella is seen at a high elevation, 30° west of the zenith;

Menkar, in the head of the Whale, is within a few degrees of the western horizon; Aries is likewise near the western horizon; and Cassiopeia is in a north-westerly direction, and at a lower altitude than in January; Deneb, in the Swan, is very near the horizon, a little to the west of the north point; Vega, in the Lyre, is just rising at a short distance to the east of it; the head of Draco is in a N. N. E. direction, about 18° above the horizon; the Great Bear is at a higher elevation than in January, and the Pointers in a direction N. N. E.; and Cor Caroli appears in a direction east by north, about midway between the zenith and the horizon.

The following constellations, among others, now appear which were under the horizon in January:—*Hydra*, the largest star in which is *Alphard*, or Cor Hydræ. It is at this time in a direction S. S. E., about 28° above the horizon. It may be distinguished from this circumstance, that there is no other considerable star near it. It is 23° S. S. W. of Regulus. The constellation *Leo*, which was only partly visible in January, now appears in its splendour towards the eastern part of the sky. Regulus, one of its largest stars, situated within half a degree of the ecliptic, is distinguished as being the largest and lowest of a group of five or six stars which form a figure or curve somewhat resembling a *sickle*. East of Regulus, at the distance of 25°, is *Denebola*, in the Lion's tail, which appears nearly in an eastern direction 35° above the horizon. East from Leo is the constellation *Virgo;* but all the stars connected with it have not at this time risen above the horizon. It is situated midway between Coma Berenices, on the north, and Corvus on the south. *Coma Berenices*, which consists of a cluster of small stars, is in a direction nearly due east, and about midway between the zenith and the horizon. East by north of this cluster at a low elevation, is Bootes, the principal star of which is *Arcturus*, of the first magnitude. It is at this time in a direction east by north, 14° degrees above the horizon. Further to the north, and at a lower elevation, is *Corona Borealis*, or the Northern Crown, the principal star in which is called *Alphacca*, of the third magnitude, and 11° east by north of *Mirac*, or ε Bootes. This constellation is distinguished by six principal stars, which are so placed as to form a circular figure, somewhat resembling a wreath or crown.

### *General Appearance of the Heavens on the 1st of May, at 9* P. M.

At this period several of the more splendid constellations which adorn our nocturnal sky during winter have disappeared. Orion is nearly hid beneath the western horizon, and only the bright star Betelguese can be faintly seen, as it is about to descend below the western point of the horizon. Aries has completely disappeared; Caput Medusæ, Taurus, the Pleiades, and Aldebaran, are just verging on the borders of the north-western horizon, and are scarcely visible; and the brilliant star Sirius has completely disappeared from the nocturnal sky. The Head of Hydra, with Alphard, its principal star, are in a south-westerly direction; Canis Minor and Procyon are in a direction W. S. W., considerably to the west of Alphard, but nearly at the same altitude. North of Procyon, at a considerable distance, are Castor and Pollux, about midway between the zenith and the western point of the horizon. At a considerable distance to the north-west of these is Capella, considerably nearer the north-western horizon than the zenith. Cassiopeia appears very low in altitude, near the northern quarter of the heavens, and the Great Bear appears near its most elevated position, not far from the zenith, the two Pointers pointing nearly directly downwards to the Pole-star, while at the same hour in November, they point almost directly upwards. Regulus is about 22° west of the meridian, at a considerable elevation; Denebola, in the same constellation (the Lion,) is just on the meridian, at a little higher altitude than Regulus. Arcturus is seen in a direction E. S. E., at a very considerable elevation, and 26° north-west of it is Cor Caroli, not very far from the zenith. The stars in the Northern Crown appear due east, midway between the zenith and the horizon. The brilliant star α Lyræ appears near the north-east, about 23½° above the horizon. The Swan is near the N. N. E. quarter of the sky, and one of its principal stars, Deneb, is about 14° above the horizon. The principal stars in Draco appear elevated 20° above α Lyræ, and nearly in the same direction.

The principal constellations which were formerly invisible are—the south-eastern portion of *Virgo*, *Libra*, *Taurus Poniatowski*, *Serpentarius*, and *Hercules*. These constellations appear near the eastern and south-eastern portions of the sky. The bright star of the first magnitude, *Spica Virginis*, which was below the horizon in March, is now elevated 24°, and may be seen in a direction S. S. E. It is 35° south-east of Denebola, and about the same distance S. S. W. of Arcturus; three stars of the first magnitude, which form a large equilateral triangle, pointing to the south. A similar triangle, pointing to the north, is formed by Arcturus, Denebola, and Cor Caroli. The principal star in Hercules is *Ras Algethi;* and *Ras Alhague*, 5° from it, in the head of Ophiuchus, may be seen nearly due east, at a small elevation

above the horizon, Ras Algethi being the brightest and the highest. Libra is situated to the south of the *Serpent*, and to the east of Virgo. Its two brightest stars are of the second magnitude; the one is named *Zubeneschamali*, 21° east of Spica Virginis, but at a much lower altitude; the other is called *Zubenelgemabi*, about 9½° above the other towards the north-east. At this time they appear in the south-east quarter of the heavens, at no great elevation above the horizon. The constellation *Serpens* lies between Corona Borealis and Libra. Its principal star is of the second magnitude, and named *Unuk*; it may be known by being nearly in the middle between two smaller stars, the lower one being 2½°, and the upper 5½° from it. It is in a direction E. S. E., at about 24° above the horizon.

*Aspect of the Heavens on the 1st of July, at 10 P.M.*

As the twilight at this season is too strong to admit of particular observations at 9 P. M., I have fixed the hour of *ten* as the most proper time for perceiving the principal stars. Most of the southern constellations which were visible in January, and which are the most brilliant, have now disappeared; and those in the north are in positions in the heavens very different from those on which they appeared in winter. The Northern Crown, the Serpent, and Libra, are now to the west of the meridian; Arcturus is considerably to the west of the meridian, but at a high elevation; immediately below which, at a considerable distance, is Spica Virginis, very near the S. W. by W. point of the horizon. Cor Caroli appears north by west of Arcturus, at a considerable distance, and at a high altitude; immediately below which, at a considerable distance, and nearly due west, is Denebola. The Great Bear is now considerably west of the meridian, at a high altitude, the two pointers pointing *eastward* to the Pole-star. Castor and Pollux have just descended below the horizon near the north-west; and Capella, which never sets in this latitude, is very near the north point, only a few degrees above the horizon. Cassiopeia is near the north-eastern quarter, at no great elevation, and α Lyræ is at a very high altitude to the east of the meridian; east of which, at a lower altitude, is Deneb, one of the principal stars in the Swan. The four stars forming the *square of Pegasus* are now seen a little to the north of the E. point, in a position nearly opposite to that in which they appeared in January. The star *Antares*, in Scorpio, of the first magnitude, is past the meridian, at an altitude of only about 11°. Ras Algethi and Alhague are nearly on the meridian.

The constellation of *Aquila*, or the Eagle, which was formerly invisible, now makes its appearance in the south-east. *Altair*, its principal star, of between the first and second magnitude, is distinguished by being nearly in the middle between two stars of the third magnitude, each of them 2° distant from it in a line bearing S.E. and N.W. Altair is at this time about 37° above the south-eastern horizon. North-east of Aquila is the *Dolphin*, at the distance of 13° or 14°. It is a beautiful little cluster of stars, consisting of about 18 in number, including five of the third magnitude, but none larger, which are so arranged as to form the figure of a diamond, pointing N.E. and S.W. It is sometimes known by the name of *Job's Coffin*. North and north-west of the Dolphin are *Sagitta*, and *Vulpecula et Anser*, or the Fox and Goose; south of Aquila is *Capricornus*, and south-east of it, *Aquarius*; but these last are more distinctly seen in the month of September. The Milky Way runs along with considerable brightness in the neighbourhood of Aquila, Vulpecula, Delphinus, and Cygnus.

*Appearances of the Sidereal Heavens on the 1st of September, at 9 P.M.*

At this time *Altair* is nearly on the meridian at an altitude of 46½°, and *Vega*, or α Lyræ, is about 16° west of the meridian, in a direction north by west from Altair. Ras Algethi and Ras Alhague are west from Altair, nearly midway between that star and the south-western point of the horizon. To the north-west of Vega is the head of Draco, at the distance of nearly 20°. Arcturus is in a position west by north, within 19° of the horizon. The Northern Crown is in a higher elevation than Arcturus, nearly due west, rather nearer the horizon than the zenith. Cor Caroli appears nearly N.W. by W. at 23° of altitude; and the Great Bear in a north-westerly direction, and at a lower altitude than formerly. To the east of the meridian, Capella is seen in a direction nearly N.N.E., at an altitude of 15°. East of Capella, at a little lower elevation, is *Menkalina*, or β Aurigæ, a star of the second magnitude. Cassiopeia appears in the north-east, about midway between the zenith and the north-eastern horizon. The Square of Pegasus is in a direction east by south, and is in a much higher elevation than in July. The Dolphin is a few degrees east of the meridian, and N.E. of Altair, at an altitude of above 50°. Along the southern quarter of the heavens are the following constellations:—Aries, in a direction east by north; Pisces, due east, and next to Aries on the west; Aquarius, to the west of Pisces, in a direction S.S.E.; Capricornus, west from Aquarius, nearly in the south; Sagittarius

and Sobieski's Shield, in a south-westerly direction, and Scorpio, which lies still further to the west. Most of these constellations, except Aries and Pisces, are at a low altitude.

### *Appearance of the Heavens on the 1st of November, at 9 P.M.*

About this time the winter constellations begin again to make their appearance in our hemisphere. The centre of the Square of Pegasus is at this season and hour nearly on the meridian; the stars Scheat and Markab, of which Scheat is the uppermost, appear on the west of the meridian, and Alpheratz and Algenib on the east. Turning our eyes to the western part of the heavens, we see the *Southern Fish*, a little to the west of the south, and its principal star, Fomalhaut, several degrees to the west of the meridian, at a very low altitude. To the west is Capricornus, and to the north-west, Aquarius. Aquila, with its principal star Altair, is in a direction west by south, at about 23° above the horizon. Deneb Cygni is at a very high elevation, about 30° west from the zenith, and α Lyræ 26° north-west of it, in a direction W.N.W., at a much lower elevation. North by west of Lyra are the two stars in the head of Draco, *Etanin* and *Rastaben*, about 4° apart. Ras Algethi and Ras Alhague are nearly due west, at a very small elevation above the horizon. The centre of the Great Bear is nearly due north, and at its lowest elevation, the stars in the tail being to the west, and the two pointers a little to the east of the northern part of the meridian, pointing upwards. Turning our view to the eastern quarter of the sky, we behold Aries in a south-easterly direction, next to Pegasus, and at a pretty high elevation. South by east of the first star in Aries is Menkar in the head of the Whale, in a direction S.E. by E., about 26° above the horizon. North-west of the first star in Aries is Mirach, and north by east Almaack, at a higher elevation, both of them in Andromeda. Near the north quarter is Capella, about midway between the zenith and the horizon. The Pleiades are seen nearly due east, followed by the ruddy star Aldebaran, at a lower elevation. Below Aldebaran, and to the south-east, the head and shoulders of Orion begin to make their appearance, Bellatrix being 4° or 5° above the horizon, and Betelguese a little lower. Cassiopeia is near the zenith, a little to the east of the meridian, and Castor and Pollux, in Gemini, are in a direction north-east, just a little above the horizon. At this time the *equinoctial colure* is only a few degrees to the east of the meridian, and the three stars *Caph* in Cassiopeia, and *Alpheratz* and *Algenib* in Pegasus, which lie in the line of its curve, may now be distinctly perceived. Caph is at the highest altitude of the three, and its distance from Alpheratz is about double the distance between Alpheratz and Algenib. If a line connecting these three stars be produced northward, it will terminate in the pole.

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The above brief sketches may enable the young observer to trace the principal stars and constellations by a few observations at different seasons of the year. The altitudes here expressed are stated in reference to places about 52° north latitude; but by making certain allowances corresponding to the latitude of the observer, the relative positions of the stars will appear nearly the same as here represented, particularly if the difference of latitude does not much exceed 10 degrees. It should be carefully remarked that the *bearings* of one star from another, as here given, are strictly true only when the star from which the bearings are given is *on or near the meridian*.—(See note, p. 88.)

As a further assistance to the astronomical tyro in distinguishing the stars, I have drawn up the following list of stars, chiefly of the first and second magnitudes, stating *the periods of the year* when they come to the meridian, or due south, *at nine o'clock in the evening.*

*Caph* in Cassiopeia, and *Alpheratz* and *Algenib*, in Pegasus, come to the meridian on *the 10th of November*, at nine o'clock in the evening. Caph is near the zenith, and the other two at a considerably lower elevation. At this time, Capella appears towards the north-east; the Pleiades, Aldebaran, and Orion, in the east; Deneb in Cygnus, in the north-west; Lyra, west-north-west; and Altair, in Aquila, west by south.

*Arietis*, or the first star of Aries, comes to the meridian on *the 5th of December.* The same stars noticed in the preceding instance are still visible, but those on the east of the meridian have risen to a higher altitude, and those on the west have descended to a lower elevation than on Nov. 10. Castor and Pollux are at this time seen towards the north-east, and Procyon, a very little above the eastern point of the horizon.

*Menkar*, in the head of the Whale, arrives at the meridian on *the 21st of December*, and at the same time the variable star *Algol*, in Medusa's head, which is 37° due north of Menkar. Altair has now disappeared from the west, and Sirius is seen at a small elevation in the south-east.

The *Pleiades* pass the meridian on *the 1st of January*, and *Aldebaran* on the 10th. When Aldebaran is due south, Capella is north by east of it near the zenith; Cor Ca-

roll, at a low altitude near the north-east; Lyra, near the horizon N. by W.; Regulus, in the east; and the head of Hydra, east by south.

*Bellatrix*, in Orion, passes the meridian on *the 21st of January*. Nearly at the same time Capella and β Aurigæ are on the meridian. These three stars are nearly equidistant in a line running north and south.

*Castor* and *Pollux* and *Procyon*. These three stars pass the meridian nearly at the same time, on *the 24th of February*. Pollux and Procyon culminate nearly at the same instant, and Castor about 11 minutes before them, at which time Procyon is 23° south of Pollux. Orion is then in a south-westerly direction; Aldebaran, midway between the meridian and the western horizon; Menkar, W. by S., at a small elevation; Sirius, S. by W.; and Capella to the west of the zenith. On the east of the meridian, Regulus is S. E.; Denebola, E.; Cor Caroli, E. N. E.; immediately below which, near the horizon, is Arcturus.

*Præcepe*, in Cancer, a small cluster of stars, just perceptible to the naked eye, like a nebula, approaches the meridian about *the 3d of March*, at an altitude of about 60°. They are N. E. of Procyon, and S. E. of Pollux. (See pp. 78–79.)

*Regulus*, in Leo, passes the meridian on *the 6th of April*. At this time, *Alphard*, in Hydra, is past the meridian S. by E. from Regulus; Procyon, S. W.; Sirius, S. W. near the horizon; Orion, very low in the west; Algenib, in Perseus, Algol, Capella, &c., towards the N. W. On the east, Denebola appears E. from Regulus; Spica Virginis, S. E. at a low altitude; Cor Caroli, E. at a high altitude; Corona Borealis, E. by N.; and Lyra, at a low altitude N. E. by N. The Great Bear, at a high altitude, approaching the zenith, and Cassiopeia, at a low altitude towards the north.

*Denebola*, in Leo, culminates on *the 3d of May*, at an altitude of 43°. Regulus is 25° west of it, and *Phad*, in the square of the Great Bear, is 39° N. of it. It forms with these two a large right-angled triangle, the right angle being at Denebola. It is nearly on the meridian with *Phad*. Other stars then visible are—Procyon. W. by S.; Capella, N. W; Arcturus, E.; Spica Virginis, S. S. E.; Lyra, N. E., &c.

*Coma Berenices*, a beautiful cluster of small stars, but scarcely distinguishable by moonlight, is on the meridian on *the 13th of May*. (See p. 78.)

*Spica Virginis* comes to the meridian on *the 23d of May*. Stars visible on the west—Capella, Castor and Pollux, and Procyon, near the western point. On the east—Lyra, Arcturus, Ras Algethi, Ras Alhague, and Altair, near the eastern horizon. Near the meridian to the west—Cor Caroli, Alioth and Mizar, in Ursa Major.

*Arcturus* is on the meridian on *the 23d of June*. The principal stars in Libra culminate at a lower altitude about the beginning of July.

*Corona Borealis* is on the meridian about *the 1st of July*. Its principal star is eleven degrees east of ε Bootes.

*Antares*, in Scorpio, passes the meridian on *the 10th of July*, at a very low altitude.

*Ras Algethi*, in Ophiuchus, and *Ras Alhague*, in Hercules, 5° apart, culminate about *the 28th of July*, nearly at the same time as the head of Draco.

*Vega*, or α Lyræ, culminates on *the 13th of August*. To the west of it, at a great distance, is Arcturus, and to the north-west, Cor Caroli. Capella is N. by E. at a low altitude; Altair, S. S. E.; and Deneb Cygni, E. at a high altitude.

*Altair*, in Aquila, is at the meridian about *the 30th of August*, at an altitude of about 46½°.

*Arided*, or *Deneb Cygni*, is on the meridian on *the 16th of September*, at an altitude of 82½°. At this time, Arcturus is W. S. W., near the horizon; Lyra and *Etanin*, in Draco, west from the meridian, but in a high elevation; Cor Caroli, N. W., at no great elevation; Hercules, S. W., midway between the meridian and the horizon; Altair, a little distance west of the S.; and the Dolphin on the meridian; the square of Pegasus in a south-eastern direction, Aries in the east, and Capella towards the north-east.

All the stars specified above, at the periods of the year stated, pass the meridian (or culminate) *at nine o'clock in the evening*. Therefore, if at any one of the periods of the year here specified, or a few days before or after it, an observer, at nine o'clock P.M., observe the principal star or stars near the meridian, he can scarcely be at a loss to recognize them, as well as some of the other principal stars and constellations on the east and west of the meridian, which are also specified in the above descriptions. A person can never become familiar with the more prominent stars, the relative position of the different constellations, and the general aspect of the heavens, *without actual observations*. Even the delineations on the celestial globe will not convey an accurate and impressive conception of the scenery of the heavens, unless the study of these delineations be accompanied with frequent surveys of the heavens themselves. It is hoped the preceding descriptions will afford some assistance to those young observers and others who wish to con-

template the sublime objects of creation with their own eyes.

N.B. In the above and the following descriptions of celestial phenomena, *altitude* signifies the height of the star or planet above the horizon; S. S. E., south-south-east; N. by E., north by east, &c. *Degrees* are marked thus °, *minutes* ′, *seconds* ″: thus, 54° 27′ 35″, expresses fifty-four *degrees*, twenty-seven *minutes* of a degree, and thirty-five *seconds*. Every degree contains 60 minutes, every minute 60 seconds, &c. When a heavenly body is said to *culminate*, the meaning is, that it has arrived at the highest point of its course, or its passage over the meridian. The term is derived from the Latin word *culmen*, the top or summit. An *occultation* signifies the obscuration of a star or planet by the interposition of the moon, or of another planet. *Conjunction* is when two or more stars or planets are in the same part of the heavens; and *opposition*, when they are 180° asunder, or in opposite parts of the heavens.

## PHENOMENA OF THE PLANETS FOR THE YEARS 1840 & 1841.

### I. POSITIONS ETC. OF THE PLANETS FOR 1840.

#### 1. *The Planet Mercury.*

This planet can be distinctly seen by the naked eye only about the time of its greatest elongation; and to those who reside in high northern latitudes it will scarcely be visible even at such periods, if it be near the utmost point of its *southern* declination.

The following are the periods of its greatest elongation for 1840: On the 8th of January, it is at its *western* elongation, when it is 23° 19′ west of the sun, and will be seen in the morning near the south-eastern part of the horizon; but as it is then 21° 45′ in southern declination, and this declination, every day on the increase, its position at that time will not be favourable for observation. Its next greatest elongation is on the 20th of March, when it will be 18½ degrees *east* of the sun, and be seen in the evening soon after sunset. This will form one of the most favourable opportunities of perceiving this planet by the naked eye, or by means of a small opera-glass. Its declination being above nine degrees north, and on the increase, it will be distinctly seen for about ten days—namely, from the 16th to the 26th of March, a little to the north of the western point of the horizon, not far from the point at which the sun sets at that period. On the 5th of May, it will again reach its greatest *western* elongation, when it will be seen in the morning before sunrise. Its declination is then 4½ degrees north, and western elongation from the sun, 26° 18′. At this period, about four o'clock in the morning, it may be seen for more than three weeks,—namely, from about the 20th of April to the 25th of May. Its direction will be nearly due east. This would form the most favourable opportunity of viewing this planet, were it not that the strong twilight at this season has a tendency to overpower its light.

In the month of July, if the long twilight do not prevent, there will be another favourable opportunity of inspecting this planet. During the whole of this month, Mercury will be at a considerable distance from the sun; but the best time for observation will be from the middle till the end of the month, as the twilight will then be less intense. It arrives at the point of its greatest *eastern* elongation on the 18th, when it is nearly 27° from the sun, and will be seen in the evening a little to the north of the western point of the compass, about forty minutes after sunset, or nearly nine o'clock P.M. Its next greatest *western* elongation will be on the 1st of September, when it is 18° 5′ west of the sun. At this period, it may be seen in the morning before five o'clock, in a direction nearly east by north, from the 27th of August to the 5th of September. On the 12th of November, it is at its next *eastern* elongation, when it will be seen after sunset near the south-western point of the horizon; but as its southern declination is at this time about 25 degrees, it will descend below the horizon nearly at the same time with the sun. The next elongation is on the 21st of December, when it is 21° 50′ *west* of the sun, and will be seen in the morning between seven and eight, near the south-east quarter of the horizon.

The periods most favourable for detecting this planet in the *evenings* are, March 20th and July 18th; and in the *mornings*, May 5th and September 1st. During the interval of a week or ten days, both before and after the time of its greatest elongation, and sometimes for three or four weeks in succession, when in high north declination, this planet may generally be seen in a clear sky when in such favourable positions as those now stated. In those regions of the globe which lie south of the equator, the planet will be in the most favourable position for observation when in *south* declination.

#### 2. *The Planet Venus.*

This planet, like Mercury, is seen alternately, in the evening towards the western quarter of the heavens, and in the morning

towards the eastern quarter. In its lustre it exceeds all the other stars and planets, and its brilliancy is such that it can scarcely be mistaken by any observer when its position in the heavens is pointed out.

Venus will be seen only in the morning from the beginning of the year till the end of July. During the months of January, February, and March, it will be seen before sunrise, chiefly in the *south-eastern* quarter of the heavens. Throughout April, May, June, and July, it will be seen in the eastern and *north-eastern* parts of the heavens. During the whole of this period, it will appear, when viewed with a telescope, either as a half-moon or with a gibbous phase. Its *superior* conjunction with the sun happens on the morning of the 25th of July, after which it becomes an *evening* star; but it will not be much noticed by common observers till about the beginning or middle of September, on account of its proximity to the sun. From this period it will continue to be seen in the evening chiefly in the *south-western* part of the sky, at a low elevation, till the end of the year. On the whole, this planet will not be very conspicuous during 1840, either to the eye of a common observer or for telescopic observation. From the beginning of September to the end of December, it will exhibit a gibbous phase, like the moon about three or four days before the full.

Venus will be in conjunction with Saturn on the 22d of January, at $2^h$ 8′ P.M., when it will be 57′ north of Saturn. It will be in conjunction with Mars on the 16th of June, at sixteen minutes past three in the morning, when Mars will be 46′ north of Venus; and it will be in conjunction with Jupiter on the 22d of October, at $8^h$ 34′ P.M., when it will be 1° 6′ south of that planet.

### 3. *The Planet Mars.*

This planet will not be very conspicuous during this year on account of its great distance from the earth, and its proximity to that part of the heavens in which the sun appears. It is in conjunction with the sun on the 4th of May, after which it will be a considerable time before it become conspicuous to the unassisted eye. Throughout the months of August and September, and the latter part of July, it will be seen early in the morning, before sunrise, near the north-eastern quarter of the heavens. From September till the end of the year, it will appear somewhat more conspicuous, but not exceeding in apparent size a star of the third magnitude. On the 1st of October it comes to the meridian at six minutes past nine in the morning, at an altitude of 52⅔° above the southern horizon. On the 1st of November, it passes the meridian at fourteen minutes past eight in the morning, at an altitude of about 46°; and on the 1st of December, it transits the meridian at nineteen minutes past seven in the morning, at an altitude of 39⅔°. At this time (1st of December,) it rises nearly due east about one in the morning and will be pretty distinguishable on account of its ruddy aspect about an hour before sunrise.

### 4. *The Planets Vesta, Juno, Ceres, and Pallas.*

These planets are not perceptible by the naked eye. The best time for observing them with telescopes is when they are at or near the period of opposition to the sun, when they are nearest the earth. Even then it will be sometimes difficult to detect them without the assistance of transit or equatorial instruments.

*Vesta* will be in opposition on the 18th of May, when it will pass the meridian at midnight, at an elevation above the horizon of 27° 34½′. Its right ascension is then $15^h$ 51′ 55½″, and its declination, 10° 25½′ south. This planet will be in conjunction with the star $\xi$ Libræ on the 1st of March, at twenty-seven minutes past five in the morning, the star being 55′ north of Vesta; it will likewise be in conjunction with the same star on the 15th of May, at noon, when the star will be 29′ south of the planet. On the 19th of July, at six in the morning, it will be in conjunction with $\gamma^1$ Libræ, when the star will be only one minute south of the planet, so that they will both appear in the same field of the telescope. On the 26th of August, at nineteen minutes past eight A.M., it will be in conjunction with $\nu$ Scorpio, when the star will be only 11′ south of Vesta. On September 3d, at eight in the evening, it will be in conjunction with $\psi$ Ophiuchi, the star 11′ north of the planet. On the 2d of October, at half-past one in the morning, it is in conjunction with Saturn, being 1° 2′ south of that planet; and on the 6th of December, at ten minutes past one in the morning, it is in conjunction with Venus, Vesta being only 11′ north of Venus.

*Pallas* will be in opposition to the sun on the 5th of July, at thirty minutes past nine in the evening. Right ascension, $18^h$ 44′ 52″; north declination, 22° 11′ 37″. It will pass the meridian about midnight, at an altitude of about 60° 11⅓′.

*Ceres* will be in opposition July 17th, at six in the morning. Right ascension, 19° 54′; south declination, 30° 8′. It will pass the meridian at an elevation somewhat less than 8°.

*Juno* will not be in opposition to the sun during 1840.

That the best time for observing these bodies is at the period of their opposition will appear from the following consideration:— that they are between two and three times nearer the earth at the time of opposition than when near the period of their conjunction with the sun; for example, Vesta is 225 millions of miles distant from the sun, and consequently only 130 millions distant from the earth at the time of opposition; but at the conjunction, its is the whole diameter of the earth's orbit = 190 millions of miles, further distant,—that is 320 millions of miles, which is a distance about two and a half times greater than when it is in opposition.

### 5. *The Planet Jupiter.*

During the months of January, February, March, and April, this planet will be seen chiefly in the morning. About the beginning of February, it will rise in a direction south-east by east, about half-past one in the morning, and will come to the meridian, at a quarter past six in the morning, at an elevation of about 22° above the southern horizon. On the 1st of March, it will rise about eight minutes before midnight, and pass the meridian about half-past four in the morning. On the 1st of April, it will rise at forty-three minutes past nine in the evening, and pass the meridian at a quarter past two in the morning. It will be in opposition to the sun, and consequently nearest the earth, on the 4th of May, when it will rise between seven and eight in the evening. From this period till the middle of November, when it is nearly in conjunction with the sun, it will be visible as an *evening* star, when it will be seen at different periods, chiefly in the south-eastern, the southern, and south-western parts of the heavens, at a comparatively low altitude; but it will not be much noticed by the naked eye after the end of September on account of its southern declination, which, for a considerable time, will be gradually increasing. Towards the end of December it will again be seen in the morning near the south-eastern quarter of the horizon. The best time for telescopic observations on this planet will be from the beginning of April till the beginning of September.

Jupiter will be in conjunction with the star $\alpha^2$ Libræ on the 15th of May, at forty-three minutes past three in the morning, when the star will appear one degree south of Jupiter; and on the 27th of August, at a quarter past two in the morning, it will be in conjunction with the same star, when it will be 34′ below Jupiter. On the 21st of November, at $4^h$ 34′ P.M., it is in conjunction with the sun. On March 5th, at three in the morning, all the satellites of Jupiter will be on the *east* of that planet, when viewed with a telescope having an erect eye-piece, and *in the order of their distances from Jupiter*. The same phenomenon will happen on the 8th of June, at thirty minutes past eleven in the evening; on the 1st of August, at half-past eight in the evening; on the 27th of August, at the same hour, but on the *west* of Jupiter; on the 20th of September, at seven P.M., on the *east* of Jupiter; and on the 16th of October, at six P.M., on the *west* of Jupiter.

This planet can scarcely be mistaken, even by a common observer, when the quarter of the heavens in which it is visible is known, as it is next to Venus in apparent magnitude and splendour. It will appear most brilliant about the end of April and the beginning of May.

### 6. *The Planet Saturn.*

This planet was in conjunction with the sun on the 6th of December, 1839; and therefore it will not be before the month of February this year that it will be in a favourable position for telescopic observation. During the months of February, March, and April, it will be seen only in the morning before sunrise, in the south-eastern quarter of the heavens, at a comparatively low altitude. On the 1st of February, it rises at half-past four in the morning, and comes to the meridian about half-past eight, at an elevation of about 16½°. On the 1st of March, it rises at forty minutes past two in the morning; on the 1st of April, at forty-two minutes past twelve, midnight; and on the first of May, it rises at forty minutes past ten in the evening. It is in opposition to the sun on the 8th of June; after which it will be seen in the evening. During the greater part of the month of May, it will likewise be seen between ten in the evening and midnight, but at a low altitude. It will continue to be visible till the month of December, but it will be difficult to distinguish it after the month of October, on account of its low altitude and its proximity to the sun. It arrives at the point of its conjunction with the sun on the 15th of December. The most favourable times and positions for taking telescopic views of this planet will be during the months of May, June, July, August, and September, especially when it is on or near the meridian. During the latter part of August and the months of October and November, about an hour after sunset, it will be seen towards the south-western quarter of the heavens, at a comparatively small elevation above the horizon.

This planet is not distinguished for its brilliancy to the naked eye; but it exhibits a most striking and beautiful appearance through a good telescope; more so than any

other planet of our system. It appears of a dull leaden colour when viewed by the naked eye, and is not easily distinguished from a fixed star except by the steadiness of its light, never presenting a *twinkling* appearance as the stars do; and from which circumstance it may be distinguished from neighbouring stars. It will be in conjunction with the star *Rho* Ophiuchi on the 5th of June, at 51 minutes past 8 P.M., when the star will be about half a degree north of the planet. It will likewise be in conjunction with the same star on the 27th of October, at 9h 36′ P.M., when the star will be fifty-four minutes of a degree north of the planet. During this year the rings of Saturn will appear to the greatest advantage, the openings of these rings being then at their utmost extent. In the beginning of October, the proportion of the longer axis to the transverse axis of the rings is nearly as 35 to 16.

### 7. *The Planet Uranus.*

This planet is for the most part invisible to the naked eye. The best time for detecting it by means of a telescope is when it is at or near the period of its opposition to the sun, which happens this year on the morning of the 11th of September. At that time it passes the meridian about midnight, at an elevation of about 32¾° above the horizon. On the 1st of August, it passes the meridian at forty minutes past two in the morning; on the 1st of October, at thirty-two minutes past ten in the evening; on the 1st of November, at twenty-seven minutes past eight; and on the 1st of December, at twenty-eight minutes past six, in the evening. Its right ascension, or distance from the first point of Aries at its opposition, September 11, is 23h 18′; and its south declination, 5° 20′ 26″. It rises during the year at points a little to the southward of the eastern point of the compass. It is in conjunction with the moon on the 9th of January, at 2h 17′ P.M., when it is 1° 27′ south of the moon. It is in conjunction with Mars on the 16th of February, at 11h 33′ P.M., when Uranus is only nine minutes of a degree to the north of Mars; so that the two planets would be seen at the same time in the field of the telescope, were not both these bodies rather too near the sun at that time for distinct observation. It is in conjunction with the sun on the 6th of March, and with the moon on the 31st, when it is 2° 1′ south of the moon. It is in conjunction with Venus on the 6th of April, at seven in the morning, when it is 40′ north of Venus. On the 25th of May, at forty-five minutes past nine in the evening, it is in conjunction with the moon, when it is 2° 39′ south of that luminary. On the 15th of August, at 3h 15′ P.M., it is again in conjunction with the moon, when it is 3° 9′ south of that luminary. On the 11th of September, at 8h 42′ P.M.; and on the 9th of October, at four in the morning, it is in conjunction with the moon, and in both cases it is then about 3° south of the moon.

N.B. In the preceding statements, the observer is supposed to be in 52° north latitude. In places a few degrees to the north or south of this latitude, a certain allowance must be made for the times of rising and the altitudes which are here specified. To those who reside in lower latitudes than 52° the altitudes of the different bodies will be *higher*, and to those in higher latitudes the altitudes will be *lower* than those which are here specified. For example; when it is stated that Saturn comes to the meridian at an altitude of 16½°, this planet will pass the meridian of a place in 42° N. latitude, at an altitude of 26½°, and the meridian of a place in 62° N. latitude, at an altitude of only 6½°. There being 10° of difference in the latitude of the supposed places, the altitude of the heavenly body will be 10° higher in the one case, and 10° lower in the other.

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## II. POSITIONS OF THE PLANETS FOR 1841.

### 1. *Mercury.*

This planet is at its superior conjunction with the sun on the 5th of February, and at its greatest elongation on the 4th of March, when it is 18° 8′ *east* of that luminary; it will therefore appear as an *evening* star, in a direction nearly due west, a little above the horizon, after sunset, between six and seven in the evening. It arrives at its inferior conjunction with the sun on the 20th March. Its next greatest *western* elongation happens on the 17th of April, when it is 27° 21′ west of that luminary. The planet will be seen about ten or twelve days before and after this time in an easterly direction, between three and four in the morning. Its next superior conjunction is on the 26th of May; and its next greatest *eastern* elongation, on the 30th of June, when it is 25° 49′ east of the sun, and consequently will be visible in the evening, in a north-westerly direction, after sunset. This would form one of the most favourable opportunities of seeing this planet, as it is then in a high north declination, were it not that the strong twilight at this season prevents small objects in the heavens from being easily distinguished. Its next greatest

elongation is on August 15th, when it is 18° 37′ west of the sun, when it will be seen in a north-easterly direction, about four in the morning. It is again at its greatest eastern elongation on the 25th of October, when it is nearly 24° east of the sun. It will be near the south-western part of the sky about sunset; but its great southern declination at that period will prevent it from being easily distinguishable. On the 3d of December, it will reach the point of its greatest western elongation, when it is 20½° west of the sun, when it may be seen for a week before and after this time, about seven in the morning, in a direction a little to the north of the south-east point of the compass, at low altitude.

### 2. *Venus.*

Venus will this year exhibit a more frequent and brilliant appearance to common observers than in 1840. It will be an evening star, first in the south-western, next in the western, and afterwards in the north-western quarter of the heavens, during the months of January, February, March, April, and the beginning of May. During the greater part of January, it will appear nearly in a south-westerly direction, and W. S. W. Throughout February, it will appear nearly west, and west by north. Throughout March, April, and the beginning of May, it will be seen in a north-westerly direction, will be visible in a pretty high elevation above the western horizon, and will continue for the most part nearly three hours above the horizon after sunset. Its greatest brilliancy is about the 8th of April, when it appears in a crescent form. When viewed by the telescope in January, it will present a *gibbous* phase, like the moon four or five days before or after the full. In February and March, it will be in the form of a *half-moon;* in April and the beginning of May, it will assume the figure of a crescent; this crescent will appear more and more slender, but more expansive, till within a few days of its inferior conjunction with the sun, which takes place on the 15th of May, about one in the morning. After this period, this planet will be seen by the naked eye only in the morning before sunrise, in an easterly and north-easterly direction, till the end of the year; but with an equatorial telescope it may be distinctly seen every clear day, even at noon, during its whole course from one conjunction to another, with the exception of only two or three weeks in the course of nineteen months. Its greatest brilliancy, after passing its inferior conjunction, is about the twentieth of June; previous to which it will appear as a crescent, and will afterwards gradually assume a half-moon and a gibbous phase.

Venus, in its course throughout this year, will pass very near some of the other planets and some of the fixed stars. The following table exhibits the times and circumstances of those conjunctions in which Venus makes the nearest approach to some of these bodies:

| | Time of conjunction. | | h. m. | Star in conjunction. | Relative position. |
|---|---|---|---|---|---|
| 1. | Jan. | 12 .... | 11 11 A.M. | σ Aquari .... | * 0° 15′ N. |
| 2. | — | 25 .... | 1 25 A.M. | Uranus .... | Ura. 0 4 N. |
| 3. | Feb. | 18 .... | 7 46 A.M. | ε Piscium.... | * 0 3 N. |
| 4. | March | 22 .... | 0 11 A.M. | ε Arietis .... | * 0 8 N. |
| 5. | April | 7 .... | 6 56 A.M. | e Pleiadum... | * 0 51 S. |
| 6. | — | 23 .... | 6 31 P.M. | The Moon .. | Ven. 0 59 N. |
| 7. | July | 12 .... | 7 43 A.M. | $\delta^1$ Tauri .... | * 0 11 S. |
| 8. | — | 12 .... | 3 52 P.M. | $\delta^2$ Tauri .... | * 0 20 S. |
| 9. | — | 13 .... | 1 4 A.M. | $\delta^3$ Tauri .... | * 0 6 N. |
| 10. | — | 24 .... | 3 40 A.M. | *m* Tauri .... | * 0 46 S. |
| 11. | — | 31 .... | 11·15 A.M. | ζ Tauri .... | * 0 57 N. |
| 12. | August | 4 .... | 9 25 A.M. | $\chi^1$ Orionis ... | * 0 14 S. |
| 13. | — | 6 .... | 1 26 P.M. | $\chi^5$ Orionis ... | * 0 30 S. |
| 14. | — | 12 .... | 3 53 A.M. | ν Geminorum . | * 0 35 S. |
| 15. | — | 19 .... | 7 12 P.M. | ζ Geminorum . | * 0 4 S. |
| 16. | Sept. | 10 .... | 2 45 A.M. | δ Cancri .... | * 0 38 N. |
| 17. | — | 12 .... | 7 50 A.M. | The Moon .. | Ven. 0 21 . |
| 18. | — | 28 .... | 0 13 A.M. | α Leonis .... | * 0 5 S. |
| 19. | Oct. | 3 .... | 7 35 A.M. | δ Leonis .... | * 0 43 S. |
| 20. | — | 10 .... | 9 2 A.M. | χ Leonis ... | * 0 15 N. |
| 21. | — | 13 .... | 9 56 P.M. | σ Leonis ... | * 0 29 N. |
| 22. | — | 26 .... | 9 42 P.M. | η Virginis ... | * 0 14 S. |

In the above table, the first column states the time of conjunction of the star or planet with Venus; the second column contains the same star or planet; and the third, the dis-

tance and position of the star or planet from Venus. N. denotes that the star is north of Venus; and S., that it is south. A.M. denotes before twelve at noon; and P.M., afternoon. In those conjunctions marked Nos. 1, 2, 3, 4, 8, 9, 12, 15, 17, 18, 20, 22, the star and the planet will be seen in the same field of view of the telescope; and although the observation should require to be made in the daytime, the star may probably be distinguished if the telescope have a great magnifying power. The conjunction of Venus with *Uranus* on the 25th of January, at twenty-five minutes past one in the morning, will afford an opportunity to amateur observers of observing this latter planet, which is invisible to the naked eye. Although both these bodies will be set to the inhabitants of Britain before the conjunction take place, yet they will be both seen in the same field of the telescope between six and eight o'clock on the preceding evening, and they will not be far distant on the evening immediately succeeding the conjunction. At New York, Philadelphia, Boston, and other parts of the United States, these planets will be seen about an hour or an hour and a half before the time of conjunction, Uranus appearing very near Venus, and uppermost, when viewed with a telescope having an erect eye-piece.

N. B. All the above and the preceding and following statements are calculated for the meridian of Greenwich, and are expressed, not in *astronomical*, but in *civil* time.

### 3. *Mars.*

During this year this planet will make a conspicuous appearance, and be seen in its brightest lustre; but its declination being *south* throughout the year, it will not rise to so high an altitude, nor remain so long above the horizon, as in some former years. During the months of January, February, and March, it will be seen only or chiefly in the morning, in a south-easterly direction. In the beginning of January, it will appear nearly in a direction east by south, soon after the time of its rising. On February the first, it comes to the meridian about five in the morning, at an altitude of about 29°; and on March the first, at thirty-seven minutes past three in the morning, at an altitude of 27°. About the middle of March, it will rise about half-past nine in the evening, and may be seen about an hour or two afterwards near the south-west quarter of the heavens. From this period, it will be seen in the evening, till the end of the year; but as its distance from the earth will rapidly increase after the months of August and September, and as it is then in a high degree of south declination, it will not be much noticed by common observers during October, November, and December. On the 18th of April, about two in the morning, it arrives at the point of its *opposition* to the sun, when it is nearest the earth, when it appears with a full enlightened hemisphere, and when it affords the best opportunities for telescopic observation. It will be most conspicuous this year in the evening, during March, April, May, June, July, and August, and will be distinguished from surrounding stars by its *ruddy* appearance. During the months of July, August, and September, it will be seen chiefly near the south-western portion of the sky. On the 11th of March it is *stationary*; that is, appears without any apparent motion; after which, its motion is *retrograde*, or contrary to the order of the signs of the Zodiac, and so continues till the 29th of May, when it is again stationary; after which its motion is *direct* or according to the order of the signs.

The planet Mars will be in conjunction with $\theta$ Virginis on the 1st of January, at thirty-two minutes past four P.M., when the star will be 17′ south of the planet. It will be in conjunction with $\kappa$ Virginis on the 4th of April, at eight o'clock in the morning, when the star will be 49′ north of Mars. It will be in conjunction with $\alpha^2$ Libræ on the 10th of August, at nineteen minutes past two P.M., the star 1° 58′ north. On the 16th of September, at fifty-three minutes past three in the morning, the star $g$ Ophiuchi will be in conjunction, at the distance of only 1′ to the south; so that the two bodies will seem almost to touch each other. On the 27th of September, about six o'clock in the evening, this planet will be in conjunction with Jupiter, when Mars will appear 2° 4′ to the south of Jupiter. On the 4th of October, at thirty-five minutes past ten P.M., it will be in conjunction with $\theta$ Ophiuchi, when the star will appear only 6′ south of the planet. On December 18th, it will be in conjunction with $\iota$ Capricorni, at $8^h$ 47′ P.M., when the star will be only eight minutes of a degree south of Mars.

### 4. *Vesta, Juno, Ceres, and Pallas.*

These planets will all be in opposition to the sun this year. *Vesta* will be in opposition on the 22d of October, at twenty-one minutes past three in the morning. It will transit the meridian about midnight, at an altitude of 38° 20′. Right ascension, $2^h$ 2′ 27″; north declination, 20′ 23″ On the 20th of April, at $1^h$ 25′ P.M., it is in conjunction with the star $p$ Piscium, the star 1° 34′ north of the planet. On the 22d of April, at $10^h$ 56′ A.M., it is in conjunction with $\tau$ Piscium, the star 1° 11′ South of Vesta. On the 24th of August, at $1^h$ 44′ A.M., the star $\nu$ Ceti will be in conjunction, the star, 14′ north of Vesta; both

these bodies will therefore be seen in the same field of a telescope.

*Juno* will be in opposition on the 19th of March at $2^h$ 45′ P.M., and will come to the meridian about midnight, at an altitude of 41° 3′. Right ascension, $11^h$ 59′ 55″; north declination, 3° 3′ 15″. Juno will be in conjunction with η Virginis on the 4th of March, at $3^h$ 24′ P.M., the star 28′ south of Juno. On the 25th of April, at noon, it will be in conjunction with ν Virginis, when the star will be only 7′ north of the planet. This conjunction will afford a favourable opportunity for detecting Juno. On the 24th of May, at $7^h$ 12′ A.M., it will again be in conjunction with ν Virginis, when the star will be 36′ south of the planet. On the 22d of June, at $8^h$ 36′ A.M., it will be in conjunction with π Virginis, the star 45′ north of the planet.

*Pallas* is in opposition to the sun on the 4th of September, at $5^h$ 34′ P.M., when it will come to the meridian at an altitude of 40° 41½′. Right ascension, $22^h$ 37′; north declination, 2° 41′ 20″. Pallas will be in conjunction with the star η Aquarii on the 20th of September, about one in the morning, when the star will be 22′ south of Pallas.

*Ceres* is in opposition on October 13th, at twenty-two minutes past eleven A.M., and comes to the meridian at that time at an elevation above the southern horizon of 32° 45½′. Right ascension, $1^h$ 35′ 20″; north declination, 5° 14′ 30″.

### 5. *Jupiter.*

This planet passed its conjunction with the sun on the 21st of November, 1840, and will appear as a *morning* star during the months of January, February, March, and April. On the 1st of January, it will rise near the south, at thirty-four minutes past five in the morning, and will pass the meridian at forty minutes past nine, at an altitude of nearly 17°. On the 1st of February, it will rise in the same quarter, at fifty-six minutes past three, and come to the meridian about eight. On the 1st of March, it will rise at twenty-two minutes past two in the morning, and pass the meridian at twenty-eight minutes past six. On the 1st of April, it rises at twenty-eight minutes past twelve, midnight; and on the 1st of May, at thirty-two minutes past ten in the evening; after which it will continue to be seen in the evening till about the middle of November. It will be in conjunction with the sun on the morning of the 23d of December, after which, it will be a morning star. The declination of Jupiter on January 1st is 21° 3½′ *south*, and on the 1st of December, 23° 13½′ south. On account, therefore, of its great southern declination, its altitude will be low, and its duration above the horizon comparatively short. Its altitude, when passing the meridian about the beginning of December, is only 14° 46′. Its opposition to the sun happens on the 5th of June, at $10^h$ 16′ P.M. It will appear chiefly in a southerly and south-westerly direction in the evenings of July, August and September. The best time for telescopic observations on this planet in the evening will be from April till the end of August.

On the 20th of April, at a quarter past three in the morning, all the satellites of Jupiter will appear on the west side of the planet, when viewed with a telescope having an erect eye-piece, and *in the order of their distances from Jupiter*. The same phenomenon will happen on the 8th of June, at thirty minutes past eleven in the evening. On the 5th and 18th of July, (on the *east* of Jupiter,) at forty-five minutes past nine in the evening; on the 27th of September, at $7^h$ 30′ P.M.; and on the 17th of November, at $5^h$ P.M.

### 6. *Saturn.*

This planet will be seen only in the morning from the beginning of January till the beginning of May. On the 1st of February, it will rise at $5^h$ 8′ A.M., in a direction nearly south-east, and will come to the meridian at $9^h$ 8′ A.M., at an altitude of 15° 35′; on the 1st of March, it rises at twenty-eight minutes past three in the morning; on the 1st of April, at thirty-one minutes past one; and on the 1st of May, at thirty-two minutes past eleven in the evening. From January till May the planet will be seen chiefly in a *south-easterly* direction in the morning, at a small elevation above the horizon. From July till October it will be seen in the evening, chiefly in a southerly and south-by-west direction. It is in opposition to the sun on the 21st of June, when it rises about eight in the evening, and passes the meridian about midnight. It will be in conjunction with the sun on the 27th of December. Its right ascension on the 1st of January is $17^h$ 43′, and its south declination, 22° 21′. On the 31st of December, its right ascension is $18^h$ 26′, and south declination, 22° 40′. On account of its great southern declination and its vicinity to the sun, it will not be much noticed during the latter part of October and the months of November and December.

During this year the ring of Saturn will be in a very favourable position for telescopic observation, the elliptical figure of the ring appearing nearly at its utmost width, so that it will appear very nearly to encompass the planet. The best periods for telescopic observations in the evening will be from the month of May, till the end of September.

7. *Uranus.*

Uranus will be in opposition to the sun on the 15th of September, at $10^h$ 17′ A.M., when it will pass the meridian about midnight, at an altitude of 34° 15′ Right ascension at this period, $23^h$ 33½′; south declination, 3° 45′. It is in conjunction with Venus on the 25th of January, at twenty-five minutes past one in the morning, and is distant from Venus only four minutes of a degree. It is in conjunction with Vesta on the 9th of April, at nine in the evening, being 3° 54′ to the north of Vesta. On the 1st of September, it passes the meridian at fifty-one minutes past twelve, midnight; on the 1st of October, at forty-nine minutes past ten in the evening; on the 1st of November, at forty-three minutes past eight; on the 1st of December, at forty-four minutes past six; and on the 1st of January, 1842, at forty-four minutes past four in the afternoon. The most eligible periods for detecting this planet by means of the telescope are the months of August, September, October, and November.

N.B. The preceding descriptions of planetary phenomena are chiefly intended to inform common observers as to the seasons of the year when the different planets may be seen, and the quarters of the heavens to which they are to direct their attention in order to distinguish them. It may be proper to observe, that the planets in general cannot be distinguished by the naked eye for about a month before and after their conjunctions with the sun, except *Venus*, which may frequently be seen within a week before and after its *inferior* conjunction; but this planet will sometimes be invisible to the naked eye for a month or two before and after its *superior* conjunction with the sun.

For a particular description of the motions, distances, magnitudes, and other phenomena in relation to the primary planets and their satellites, the reader is respectfully referred to the volume entitled "Celestial Scenery; or the Wonders of the Planetary System Displayed," where all the most interesting facts connected with the solar system, and the scenery it displays, are particularly detailed.

## ECLIPSES AND OCCULTATIONS.

### ECLIPSES IN 1840.

There will be four eclipses this year, two of the sun and two of the moon; but none of them will be visible within the limits of the British isles, nor in the United States of America, except a partial eclipse of the moon, August 13th, at $7^h$ 23′ A.M., Greenwich time. This eclipse will be visible at Philadelphia, New York, Boston, and most parts of North America, but not in Britain. On March 4th, there will be an *annular* eclipse of the sun, the middle of which will happen at $7^h$ 23′ A.M.; and on August 27th there will be a total eclipse of the sun; middle of the eclipse about $7^h$ A.M. These two interesting eclipses will be visible chiefly in the eastern parts of the globe, in the eastern parts of Africa, the East Indies, the Indian Ocean, Australia, &c. At the Cape of Good Hope, there will be a *partial* eclipse of the sun on August 27th; but both eclipses will be invisible both in Britain and America.

### ECLIPSES IN 1841.

This year there will be six eclipses, four of the *sun* and two of the *moon*, at the following times:—Of the *sun*, January 22d, at $5^h$ 23′, a partial eclipse, visible only in a small portion of the southern ocean; of the *moon*, February 6th, at $2^h$ 6′ A.M., visible in Great Britain; of the *sun*, a partial eclipse, February 21st, at $11^h$ 4′ A.M., visible chiefly in the North Atlantic Ocean, Iceland, and East Greenland; of the *sun*, a partial eclipse, July 18, at $2^h$ 24′ P.M., visible in Baffin's Bay, Iceland, Norway, Sweden, Russia in Europe, Prussia, Germany, Scotland, &c., but invisible at Greenwich; of the *moon*, a *total* eclipse, August 2d, at $10^h$ 1′ A.M.; of the *sun*, a partial eclipse, August 16th, at $9^h$ 19′ P.M., visible chiefly in the South Pacific Ocean. The times here specified denote the *middle* of the eclipse.

All the above eclipses are invisible at Greenwich, and in most parts of Britain, except the total eclipse of the moon on February 5th and 6th, of which the following is a more particular detail in mean time at Greenwich:

| | h. | m. | |
|---|---|---|---|
| First contact with penumbra of the earth's shadow, Feb. 5. | 11 | 24 | P.M. |
| First contact with dark shadow, Feb. 6. | 0 | 20 | A.M. |
| First total immersion in dark shadow, Feb. 6. | 1 | 17 | A.M. |
| Middle of the eclipse, Feb, 6. | 2 | 6½ | A.M. |
| Last total immersion in dark shadow, Feb, 6. | 2 | 55½ | A.M. |
| Last contact with dark shadow, Feb. 6. | 3 | 52¾ | A.M. |
| Last contact with penumbra, Feb 6. | 4 | 49 | A.M. |

Digits eclipsed, 20½.

A large *solar* eclipse will be visible on

July 8, 1842; and no eclipse of the sun will be visible in Britain till that time. That eclipse will be *total* in the southern parts of France, and large even in and near London. At Greenwich, it will begin at $4^h$ $53\frac{1}{2}'$ A.M., and end at $6^h$ $43'$. Digits eclipsed, $9°$ $42\frac{1}{2}'$. Of course this eclipse will not be visible in the United States, nor throughout any part of America, as the sun will not at that time be risen to those places.

### OCCULTATIONS OF VENUS BY THE MOON IN 1841.

On the 26th of March, 1841, the planet Venus will suffer an occultation by the moon. It will begin to be immersed behind the moon at forty minutes past two o'clock in the afternoon, of Greenwich mean time, and will emerge from behind the opposite limb of the moon at twenty-three minutes past 3 P.M. Another occultation of Venus will happen on the 12th of September, 1841; immersion, thirty minutes past six in the morning; emersion, forty-two minutes past 7 A.M. In the occultation of March 26, Venus will be nearly in the form of a half-moon, and the moon in the form of a crescent. Venus will be immerged at the dark (or eastern) limb of the moon, and will emerge from the enlightened crescent. They will be then nearly on the meridian, at an altitude of about 60°, and nearly three hours of right ascension east of the sun. A short time after sunset, Venus will be seen a little west from the lunar crescent, but very near it, shining with considerable splendour. Although this occultation will happen while the sun is above the horizon, yet both the moon and Venus will be easily perceived with a common telescope of very moderate magnifying power. In the occultation which takes place on the morning of September 12, Venus will, as in the former case, be nearly in the shape of a half-moon, and the moon a slender crescent, being only $2\frac{1}{2}$ days from the period of conjunction or new moon. In this case Venus will be immerged at the enlightened limb of the moon, and emerge from the dark limb. Both bodies will be then in an easterly or north-easterly direction, and the immersion will take place a little after sunrise; about half an hour before which, Venus will be seen a very little to the east of the moon.

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## EXPLANATIONS OF SOME OF THE ENGRAVINGS OF THE STARS.

PLATES I. and II., which represent portions of the heavens as seen about the middle of January and the 1st of September, have been explained pp. 14—17; and PLATE III., which represents the north circumpolar stars has been explained pp. 17—21.

PLATE IV. represents some of the larger stars and principal constellations around the *South Pole*, to the distance of 45° from that pole. It also shows a portion of the Milky Way which traverses that region of the heavens, and which is said to appear there with peculiar brilliancy. One of the principal constellations which is frequently noticed, and which appears peculiarly striking to sea-faring people and others, is called *Crux*, or the *Cross*, from the resemblance it bears to that figure. It consists of five stars, one of the first magnitude, two of the second, one of the third, and one of the fourth magnitude. Four of these are in the position of the cross; the northermost and southermost of which are always in a line with the south pole, and therefore serve for a direction in south latitude to discover that pole, as the Two Pointers in the Great Bear serve to direct the eye to the *North* Polar-star. There is no large or prominent star at or near the South Pole. This constellation is represented near the line, or meridian, which points at XII., opposite to the month of *May*. All its stars, except the lowermost, appear within the limits of the Milky Way. The stars immediately below the Cross belong to the *Centaur*; those on the left, opposite *April*, belong to *Robur Caroli*, or King Charles's Oak, which contains a star of the first magnitude. Further to the left, opposite *March*, is *Argo Navis* or the *Ship*. Still further to the left, opposite *February*, is *Pisces Volans*, the Flying Fish, which contains a star of the first magnitude, named *Canopus*. This star is marked near the left side of the map, opposite the middle of February. To the *right* from the Cross are the two fore legs of the Centaur, distinguished by two stars of the first magnitude, named *Agena* and *Bungula*, Agena being the one next to the Cross. They are in the Milky Way, and appear opposite the month of *June*. Next to the Cross and the Centaur, on the right, are *Circinus*, or the Compasses; the Southern *Triangle*, which contains three stars of the second magnitude in the form of a triangle; and *Ara*, or the Altar, which lies adjacent to the right hand side of the map, opposite the space between *July* and *August*.

Directing our attention to the upper part of the map, on the left, there is the constellation *Equuleus Pictoria*, or the Painter's Easel, which consists of a number of small stars. Next to this, and a little above it, is *Dorado*, or the Sword Fish, which contains two or three stars of the second and third magnitudes. To the right of Dorado is *Hydrus*, or the Water Snake; above which

is *Achernar*, a star of the first magnitude in *Eridanus*, which appears opposite the 1st of *December*. Next to Achernar, on the right is *Toucana*, or the American Goose; above which, opposite *November*, is the *Phœnix*; to the right of which is the *Crane*, which contains two stars of the second magnitude; below which is *Pavo*, or the Peacock, which contains several stars of the second and third magnitudes; below Pavo, opposite to August, is *Telescopium*, or the Telescope, which contains no remarkable stars. Within eleven degrees of the South Pole, represented by the central point of the map, are two of those whitish or nebulous spaces called the *Magellanic Clouds*, which are found by the telescope to consist of small stars and nebulous appearances. The other Magellanic cloud, which is the largest, is at a considerable distance from the South Pole. In specifying the names of some of the above stated constellations, the *incongruity* of the animals

## PLATE IV.

### THE SOUTH CIRCUMPOLAR STARS.

and figures by which these groups of stars are represented will at once be apparent to the reader.

PLATE V. contains a condensed representation of some of the principal constellations in the northern and southern hemispheres on *Mercator's Projection*, chiefly for the purpose of exhibiting THE COURSE OF THE MILKY WAY, and the relative positions of the constellations. Some of the larger stars may be here traced as α Lyræ, Capella, &c., but they are more easily distinguished in the other maps. (See the description given of the Milky Way, p. 71.)

Fig. 80 (p. 158) represents the comet of 1661, as seen by Hevelius; the atmosphere, or nebulosity, surrounding the nucleus, when viewed at different times, varied in its extent, as likewise the tail in its length and breadth.

Fig. 81 (p. 158) represents a class of comets which have their tails somewhat bent, which some suppose to be owing to the re-

sistance of the ethereal fluid through which they move.

Fig. 85 represents a telescopic view of the *Pleiades*, a group of stars in the constellation Taurus. About forty stars are here represented, but with powerful telescopes many more may be discovered. *Rheita* affirms that he counted 200 stars within this cluster, and yet telescopes, at the period when he lived, had not arrived at the point of perfection they have now attained. The principal star in the Pleiades is *Alcione*, of the third magnitude, which is here represented near the centre of the cluster. The names of the others visible to the naked eye are Merope, Maia, Electra, Tayeta, Sterope, and Celino.

Fig. 85.

*The principal Stars composing the Pleiades.*

Merope is the one which some suppose to have been lost. In fabulous history, these stars were the seven daughters of Atlas and the nymph Pleione, who were turned into stars with their sisters the Hyades, on account of their mutual affection and amiable virtues.

The other five stars, besides Alcione, are of the fifth magnitude, as represented in the plate; and the rest are telescopic stars of the sixth, seventh, eighth, and ninth magnitudes. The lines from right to left are portions of circles of declination, which run parallel with the equinoctial, as the parallels of latitude on the terrestrial globe do with respect to the equator; and on these the *declination*, or distance of the body from the equinoctial, is marked. The other lines, from top to bottom, are portions of circles of right ascension con-

responding with meridians on the terrestrial globe. On these are marked the right ascensions of the heavenly bodies or their distance, reckoned on the equinoctial from the first point of Aries. One of these lines, at the top and bottom, is marked 54°, showing that the stars in that line are 54° east from the first point of Aries; and the number 23, marked at the right and left hand sides, shows that the star or stars in that line are 23° north of the equinoctial.

Fig. 86 represents the tail of the splendid comet of 1744, which was divided into six branches, as described p. 161. See also the description given of this comet, pp. 154, 155.

Fig. 86.

THE

# PRACTICAL ASTRONOMER.

COMPRISING

ILLUSTRATIONS OF LIGHT AND COLOURS—PRACTICAL DESCRIPTIONS OF ALL KINDS OF TELESCOPES—THE USE OF THE EQUATORIAL-TRANSIT—CIRCULAR, AND OTHER ASTRONOMICAL OBSERVATIONS,

A PARTICULAR ACCOUNT OF THE

## EARL OF ROSSE'S LARGE TELESCOPES,

AND OTHER TOPICS CONNECTED WITH ASTRONOMY.

BY THOMAS DICK, LL. D.,

AUTHOR OF "THE CHRISTIAN PHILOSOPHER,"—"CELESTIAL SCENERY,"—"SIDEREAL HEAVENS," etc., etc.

HARTFORD:
PUBLISHED BY A. C. GOODMAN & CO.

1850.

# PREFACE.

THE following work was announced several years ago in the preface to the volume on "The Sidereal Heavens," since which time numerous inquiries have been made after it by correspondents in England, the West Indies, and America. It was nearly ready for publication three years ago, but circumstances over which the author had no control prevented its appearance at that period. This delay, however, has enabled him to introduce descriptions of certain instruments and inventions which were partly unknown at the time to which he refers.

The term "Practical Astronomer" has been fixed upon as the shortest that could be selected, although the volume does not comprise a variety of topics and discussions generally comprehended in this department of astronomy. The work is intended for the information of general readers, especially for those who have acquired a relish for astronomical pursuits, and who wish to become acquainted with the instruments by which celestial observations are made, and to apply their mechanical skill to the construction of some of those which they may wish to possess. With this view, the author has entered into a variety of minute details, in reference to the construction and practical application of all kinds of telescopes, &c., which are not to be found in general treatises on Optics and Astronomy.

As *Light* is the foundation of astronomical science, and of all the instruments used for celestial observation, a brief description is given of the general properties of light—of the laws by which it is refracted and reflected when passing through different mediums, and of the effects it produces in the system of nature—in order to prepare the way for a clear understanding of the principles on which optical instruments are constructed, and the effects they produce.

As this, as well as every other physical subject, forms a part of the arrangements of the Creator throughout the material system, the author has occasionally taken an opportunity of directing the attention of the reader to the Wisdom and Beneficence of the Great First Cause, and of introducing those moral reflections which naturally flow from the subject.

The present is the ninth volume which the author has presented to the public, and he indulges the hope that it will meet with the same favourable reception which his former publications have uniformly experienced. It was originally intended to conclude the volume with a few remarks on the *utility* of astronomical studies, and their *moral* and *religious* tendency, but this has been prevented, for the present, in consequence of the work having swelled to a greater size than was anticipated. Should he again appear before the public as an author, the subject of discussion and illustration will have a more direct bearing than the present on the great objects of religion and a future world.

BROUGHTY FERRY, near DUNDEE,
*August*, 1845.

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THE

# PRACTICAL ASTRONOMER.

## PART I.

## ON LIGHT.

### INTRODUCTION.

Light is that invisible ethereal matter which renders objects perceptible by the visual organs. It appears to be distributed throughout the immensity of the universe, and is essentially requisite to the enjoyment of every rank of perceptive existence. It is by the agency of this mysterious substance that we become acquainted with the beauties and sublimities of the universe, and the wonderful operations of the Almighty Creator. Without its universal influence, an impenetrable veil would be thrown over the distant scenes of creation; the sun, the moon, the planets, and the starry orbs would be shrouded in the deepest darkness, and the variegated surface of the globe on which we dwell would be almost unnoticed and unknown. Creation would disappear, a mysterious gloom would surround the mind of every intelligence, all around would appear a dismal waste and an undistinguished chaos. To whatever quarter we might turn, no form nor comeliness would be seen, and scarcely a trace of the perfections and agency of an All Wise and Almighty Being could be perceived throughout the universal gloom. In short, without the influence of light, no world could be inhabited, no animated being could subsist in the manner it now does, no knowledge could be acquired of the works of God, and happiness, even in the lowest degree, could scarcely be enjoyed by any organized intelligence.

We have never yet known what it is to live in a world deprived of this delightful visitant; for in the darkest night we enjoy a share of its beneficial agency, and even in the deepest dungeon its influence is not altogether unfelt.* The blind, indeed, do not directly enjoy the advantages of light, but its influence is reflected upon them, and their knowledge is promoted through the medium of those who enjoy the use of their visual organs. Were all the inhabitants of the world deprived of their eyesight, neither knowledge nor happiness, such as we now possess, could possibly be enjoyed.

There is nothing which so strikingly displays the beneficial and enlivening effects of light as the dawn of a mild morning after a night of darkness and tempest. All appears gloom and desolation in our terrestrial abode till a faint light begins to whiten the eastern horizon. Every succeeding moment brings along with it something new and enlivening. The crescent of light towards the east now expands its dimensions, and rises upward towards the cope of heaven; and objects, which a little before were immersed in the deepest gloom, begin to be clearly distinguished. At length the sun arises, and all nature is animated by his appearance; the magnificent scene of creation, which a little before was involved in obscurity, opens gradually to view; and every object around excites sentiments of wonder, delight, and adoration. The radiance which emanates from this luminary

* Those unfortunate individuals who have been confined in the darkest dungeons have declared, that though, on their first entrance, no object could be perceived, perhaps for a day or two, yet, in the course of time, as the pupils of their eyes expanded, they could readily perceive mice, rats, and other animals that infested their cells, and likewise the walls of their apartments; which shows that, even in such situations, light is present, and produces a certain degree of influence.

displays before us a world strewed with blessings, and embellished with the most beautiful attire. It unveils the lofty mountains and the forests with which they are crowned; the fruitful fields, with the crops that cover them; the meadows, with the rivers which water and refresh them; the plains adorned with verdure; the placid lake, and the expansive ocean. It removes the curtain of darkness from the abodes of men, and shows us the cities, towns, and villages, the lofty domes, the glittering spires, and the palaces and temples with which the landscape is adorned. The flowers expand their buds and put forth their colours, the birds awake to melody, man goes forth to his labour, the sounds of human voices are heard, and all appears life and activity, as if a new world had emerged from the darkness of chaos.

The whole of this splendid scene, which light produces, may be considered as a new creation, no less grand and beneficent than the first creation, when the command was issued, "Let there be light, and light was." The aurora and the rising sun cause the earth, and all the objects which adorn its surface, to arise out of that profound darkness and apparent desolation which deprived us of the view of them as if they had been no more. It may be affirmed, in full accordance with truth, that the efflux of light in the dawn of the morning, after a dark and cloudy night, is even more magnificent and exhilarating than at the first moment of its creation. At that period there were no spectators on earth to admire its glorious effects; and no objects, such as we now behold, to be embellished with its radiance. The earth was a shapeless chaos, where no beauty or order could be perceived; the mountains had not reared their heads; the seas were not collected into their channels; no rivers rolled through the valleys; no verdure adorned the plains; the atmosphere was not raised on high to reflect the radiance, and no animated beings existed to diversify and enliven the scene. But now, when the dawning of the morning scatters the darkness of the night, it opens to view a scene of beauty and magnificence, The heavens are adorned with azure, the clouds are tinged with the most lively colours, the mountains and plains are clothed with verdure, and the whole of this lower creation stands forth arrayed with diversified scenes of beneficence and grandeur, while the contemplative eye looks round and wonders.

Such, then, are the important and beneficent effects of that *light* which every moment diffuses its blessings around us. It may justly be considered as one of the most essential substances connected with the system of the material universe, and which gives efficiency to all the other principles and arrangements of nature. Hence we are informed, in the sacred history, that light was the first production of the Almighty Creator, and the first born of created beings; for without it the universe would have presented nothing but an immense blank to all sentient existences. Hence, likewise, the Divine Being is metaphorically represented under the idea of *light*, as being the source of knowledge and felicity to all subordinate intelligences: "God is light, and in Him is no darkness at all;" and he is exhibited as "dwelling in light unapproachable and full of glory, whom no man hath seen or can see." In allusion to these circumstances, Milton, in his Paradise Lost, introduces the following beautiful apostrophe:

"Hail holy light! offspring of heaven first born;
Or of the eternal, coeternal beam!
May I express thee unblamed? since God is light
And never but in unapproached light
Dwelt from eternity; dwelt then in thee,
Bright effluence of bright essence increate.
———Before the sun,
Before the heavens thou wert, and at the voice
Of God, as with a mantle, didst invest
The rising world of waters dark and deep,
Won from the void and formless infinite."

As light is an element of so much importance and utility in the system of nature, so we find that arrangements have been made for its universal diffusion throughout all the worlds in the universe. The sun is one of the principal sources of light to this earth on which we dwell, and to all the other planetary bodies; and, in order that it may be *equally* distributed over every portion of the surfaces of these globes, to suit the exigencies of their inhabitants, they are endowed with a motion of rotation, by which every part of their surfaces is alternately turned towards the source of light; and when one hemisphere is deprived of the direct influence of the solar rays, its inhabitants derive a portion of light from luminaries in more distant regions, and have their views directed to other suns and systems, dispersed, in countless numbers, throughout the remote spaces of the universe. Around several of the planets, satellites or moons have been arranged for the purpose of throwing light on their surfaces in the absence of the sun, while, at the same time, the primary planets themselves reflect an effulgence of light upon their satellites. All the stars which our unassisted vision can discern in the midnight sky, and the millions more which the telescope alone enables us to descry, must be considered as so many fountains of light, not merely to illuminate the voids of immensity, but to irradiate with their beams surrounding worlds with which they are more immediately connected, and to diffuse a general lustre throughout the amplitudes of infi-

nite space; and, therefore, we have every reason to believe that, could we fly, for thousands of years, with the swiftness of a seraph, through the spaces of immensity, we should never approach a region of absolute darkness, but should find ourselves every moment encompassed with the emanations of light, and cheered with its benign influences. That Almighty Being who inhabiteth immensity and "dwells in light inaccessible," evidently appears to have diffused light over the remotest spaces of his creation, and to have thrown a radiance upon all the provinces of his wide and eternal empire, so that every intellectual being, wherever existing, may feel its beneficent effects, and be enabled, through its agency, to trace his wonderful operations, and the glorious attributes with which he is invested.

As the science of astronomy depends solely on the influence of light upon the organ of vision, which is the most noble and extensive of all our senses; and as the construction of telescopes and other astronomical instruments is founded upon our knowledge of the nature of light and the laws by which it operates, it is essentially requisite, before proceeding to a description of such instruments, to take a cursory view of its nature and properties, in so far as they have been ascertained, and the effects it produces when obstructed by certain bodies, or when passing through different mediums.

## CHAPTER I.

### *General Properties of Light.*

It is not my intention to discuss the subject of light in minute detail, a subject which is of considerable extent, and which would require a separate treatise to illustrate it in all its aspects and bearings. All that I propose is to offer a few illustrations of its general properties, and the laws by which it is refracted and reflected, so as to prepare the way for explaining the nature and construction of telescopes and other optical instruments.

There is no branch of natural science more deserving of our study and investigation than that which relates to light, whether we consider its beautiful and extensive effects, the magnificence and grandeur of the objects it unfolds to view, the numerous and diversified phenomena it exhibits, the optical instruments which a knowledge of its properties has enabled us to construct, or the daily advantages we derive, as social beings, from its universal diffusion. If air, which serves as the medium of sound and the vehicle of speech, enables us to carry on an interchange of thought and affection with our fellow men, how much more extensively is that intercourse increased by light, which presents the images of our friends and other objects as it were immediately before us, in all their interesting forms and aspects—the speaking eye, the rosy cheeks, the benevolent smile, and the intellectual forehead. The eye, more susceptible of multifarious impressions than the other senses, "takes in at once the landscape of the world," and enables us to distinguish, in a moment, the shapes and forms of all its objects, their relative positions, the colours that adorn them, their diversified aspect, and the motions by which they are transported from one portion of space to another. Light, through the medium of the eye, not only unfolds to us the persons of others, in all their minute modifications and peculiarities, but exhibits us to ourselves. It presents to our own vision a faithful portrait of peculiar features behind reflecting substances, without which property we should remain entirely ignorant of those traits of countenance which characterize us in the eyes of others.

But what is the nature of this substance we call *light*, which thus unfolds to us the scenes of creation? On this subject two leading opinions have prevailed in the philosophical world. One of those opinions is, that the whole sphere of the universe is filled with a subtile matter, which receives from luminous bodies an agitation which is incessantly continued, and which, by its vibratory motions, enables us to perceive luminous bodies. According to this opinion, light may be considered as analogous to sound, which is conveyed to the ear by the vibratory motions of the air. This was the hypothesis of Descartes, which was adopted, with some modifications, by the celebrated Euler, Huygens, Franklin, and other philosophers, and has been admitted by several scientific gentlemen of the present day. The other opinion is, that light consists of the emission or emanation of the particles of luminous bodies, thrown out incessantly on all sides, in consequence of the continued agitation it experiences. This is the hypothesis of the illustrious Newton, and has been most generally adopted by British philosophers.

To the first hypothesis it is objected that, if true, "light would not only spread itself in a direct line, but its motion would be transmitted in every direction like that of sound, and would convey the impression of luminous

bodies in the regions of space beyond the obstacles that intervene to stop its progress." No wall or other opaque body could obstruct its course, if it undulated in every direction like sound; and it would be a necessary consequence, that we should have no night, nor any such phenomena as eclipses of the sun or moon, or of the satellites of Jupiter and Saturn. This objection has never been very satisfactorily answered. On the other hand, Euler brings forward the following objections against the Newtonian doctrine of emanation. 1. That, were the sun emitting continually, and in all directions, such floods of luminous matter, with a velocity so prodigious, he must speedily be exhausted, or at least some alteration must, after the lapse of so many ages, be perceptible. 2. That the sun is not the only body that emits rays, but that all the stars have the same quality; and as every where the rays of the sun must be crossing the rays of the stars, their collision must be violent in the extreme, and that their direction must be changed by such a collision.*

To the first of these objections it is answered, that so vast is the tenuity of light, that it utterly exceeds the power of conception; the most delicate instrument having never been certainly put in motion by the impulse of the accumulated sunbeams. It has been calculated that in the space of 385,130,000 Egyptian years (of 360 days,) the sun would lose only the $\frac{1}{1,217,420}$th of his bulk from he continual efflux of his light. And, therefore, if in 385 *millions* of years the sun's diminution would be so extremely small, it would be altogether insensible during the comparatively short period of five or six thousand years. To the second objection it is replied, that the particles of light are so extremely rare that their distance from one to another is incomparably greater than their diameters; that all objections of this kind vanish when we attend to the continuation of the impression upon the retina, and to the small number of luminous particles which are on that account necessary for producing constant vision. For it appears, from the accurate experiments of M. D'Arcy, that the impression of light upon the retina continues *eight thirds*, and as a particle of light would move through 26,000 miles in that time, constant vision would be maintained by a succession of luminous particles twenty-six thousand miles distant from each other.

Without attempting to decide on the merits of these two hypotheses, I shall leave the reader to adopt that opinion which he may judge to be attended with the fewest difficulties, and proceed to illustrate some of the *properties of light;* and in the discussion of this subject I shall generally adhere to the terms employed by those who have adopted the hypothesis of the *emanation* of light.

1. *Light emanates or radiates from luminous bodies in a straight line.* This property is proved by the impossibility of seeing light through bent tubes, or small holes pierced in metallic plates placed one behind another, except the holes be placed in a straight line. If we endeavour to look at the sun or a candle through the bore of a bended pipe, we cannot perceive the object, nor any light proceeding from it, but through a straight pipe the object may be perceived. This is likewise evident from the form of the rays of light that penetrate a dark room, which proceed straight forward in lines proceeding from the luminous body; and from the form of the *shadows* which bodies project that are bounded by right lines passing from the luminous body, and meeting the lines which terminate the interposing body. This property may be demonstrated to the eye by causing light to pass through small holes into a dark room filled with smoke or dust. It is to be understood, however, that in this case the rays of light are considered as passing through the same medium; for when they pass from air into water, glass, or other media, they are bent at the point where they enter a different medium, as we shall afterward have occasion to explain.

2. *Light moves with amazing velocity.* The ancients believed that it was propagated from the sun and other luminous bodies *instantaneously;* but the observations of modern astronomers have demonstrated that this is an erroneous hypothesis, and that light, like other projectiles, occupies a certain time in passing from one part of space to another. Its velocity, however, is prodigious, and exceeds that of any other body with which we are acquainted. It flies across the earth's orbit, a space 190 millions of miles in extent, in the course of sixteen and a half minutes, which is at the rate of 192,000 miles every second, and more than a million of times swifter than a cannon ball flying with its greatest velocity. It appears from the discoveries of Dr. Bradley, respecting the aberration of the stars, that light flies from those bodies with a velocity similar, if not exactly the same; so that the light of the sun, the planets, the stars, and every luminous body in the universe is propagated with *uniform* velocity.* But, if the velocity of light be so very great, it may be asked, how does it not strike against all objects with a force equal to

* Letters to a German Princess, vol. i. p. 68, &c.

* The manner in which the motion of light was discovered is explained in the author's work, entitled, "Celestial Scenery; and the circumstances which led to the discovery of the aberration of light are stated and illustrated in his volume on the "Sidereal Heavens."

its velocity? If the finest sand were thrown against our bodies with the hundredth part of this velocity, each grain would pierce us as certainly as the sharpest and swiftest arrows from a bow. It is a principle in mechanics that the force with which all bodies strike is in proportion to the size of these bodies, or the quantity of matter they contain, multiplied by the velocity with which they move. Therefore, if the particles of light were not almost infinitely small, they would, of necessity, prove destructive in the highest degree. If a particle of light were equal in size to the twelve hundred thousandth part of a small grain of sand—supposing light to be material—we should be no more able to withstand its force than we should that of sand shot point blank from the mouth of a cannon. Every object would be battered and perforated by such celestial artillery, till our world were laid in ruins, and every living being destroyed. And herein are the wisdom and benevolence of the Creator displayed in making the particles of light so extremely small as to render them in some degree proportionate to the greatness of the force with which they are impelled; otherwise, all nature would have been thrown into ruin and confusion, and the great globes of the universe shattered to atoms.

We have many proofs, besides the above, that the particles of light are next to infinitely small. We find that they penetrate with facility the hardest substances, such as crystal, glass, various kinds of precious stones, and even the diamond itself, though among the hardest of stones; for such bodies could not be transparent, unless light found an easy passage through their pores. When a candle is lighted in an elevated situation, in the space of a second or two it will fill a cubical space (if there be no interruption) of two miles around it, in every direction, with luminous particles, before the least sensible part of its substance is lost by the candle: that is, it will in a short instant fill a sphere four miles in diameter, twelve and a half miles in circumference, and containing thirty-three and a half cubical miles, with particles of light; for an eye placed in any part of this cubical space would perceive the light emitted by the candle. It has been calculated that the number of particles of light contained in such a space cannot be less than *four hundred septillions*—a number which is *six billions* of times greater than the number of grains of sand which could be contained in the whole earth considered as a solid globe, and supposing each cubic inch of it to contain ten hundred thousand grains. Such is the inconceivable tenuity of that substance which emanates from all luminous bodies, and which gives beauty and splendour to the universe! This may also be evinced by the following experiment: Make a small pin-hole in a piece of black paper, and hold the paper upright facing a row of candles placed near each other, and at a little distance behind the black paper place a piece of white pasteboard. On this pasteboard the rays which flow from all the candles through the small hole in the black paper, will form as many specks of light as there are candles, each speck being as clear and distinct as if there were only one speck from a single candle. This experiment shows that the streams of light from the different candles pass through the small hole without confusion, and, consequently, that the particles of light are exceedingly small. For the same reason we can easily see through a small hole not more than $\frac{1}{100}$th of an inch in diameter, the sky, the trees, houses, and nearly all the objects in an extensive landscape, occupying nearly an entire hemisphere, the light of all which may pass through this small aperture.

3. *Light is sent forth in all directions from every visible point of luminous bodies.* If we hold a sheet of paper before a candle, or the sun, or any other source of light, we shall find that the paper is illuminated in whatever position we hold it, provided the light is not obstructed by its edge or by any other body. Hence, wherever a spectator is placed with regard to a luminous body, every point of that part of its surface which is toward him will be visible, when no intervening object intercepts the passage of the light. Hence, likewise, it follows that the sun illuminates not only an immense plane extending along the paths of the planets, from the one side of the orbit of Uranus to the other, but the whole of that sphere, or solid space, of which the distance of Uranus is the radius. The diameter of this sphere is three thousand six hundred *millions* of miles, and it consequently contains about 24,000,000,000,000,000,000,000,000,000, or twenty-four thousand *quartillions* of cubical miles, every point of which immense space is filled with the solar beams. Not only so, but the whole cubical space which intervenes between the sun and the nearest fixed stars is more or less illuminated by his rays. For, at the distance of Sirius, or any other of the nearest stars, the sun would be visible, though only as a small, twinkling orb; and, consequently, his rays must be diffused, however faint, throughout the most distant spaces whence he is visible. The diameter of this immense sphere of light cannot be less than *forty billions* of miles, and its solid contents 33,500,000,000,000,000,000,000,000,000,000,000,000,000, or thirty-three thousand five hundred *sextillions* of

cubical miles. All this immense and incomprehensible space is filled with the radiations of the solar orb; for were an eye placed in any one point of it, where no extraneous body interposed, the sun would be visible either as a large luminous orb, or as a small twinkling star. But he can be visible only by the rays he emits, and which enter the organs of vision. How inconceivably immense, then, must be the quantity of rays which are thrown off in all directions from that luminary which is the source of our day! Every star must likewise be considered as emitting innumerable streams of radiance over a space equally extensive; so that no point in the universe can be conceived where absolute darkness prevails, unless in the *interior* regions of planetary bodies.

4. *The effect of light upon the eye is not instantaneous, but continues for a short space of time.* This may be proved and illustrated by the following examples: if a stick, or a ball connected with a string, be whirled round in a circle, and a certain degree of velocity given it, the object will appear to fill the whole circle it describes. If a lighted firebrand be whirled round in the same rapid manner, a complete circle of light will be exhibited. This experiment obviously shows that the impression made on the eye by the light from the ball or the firebrand, when in any given point of the circle, is sufficiently lasting to remain till it has described the whole circle, and again renews its effect as often as the circular motion is continued. The same is proved by the following considerations: we are continually shutting our eyes, *or winking;* and, during the time our eyes are shut on such occasions, we should lose the view of surrounding objects if the impression of light did not continue a certain time while the eyelid covers the pupil; but experience proves that during such vibrations of the eyelids the light from surrounding objects is not sensibly intercepted. If we look for some time steadily at the light of a candle, and particularly if we look directly at the sun, without any interposing medium, or if we look for any considerable time at this luminary through a telescope with a coloured glass interposed—in all these cases, if we shut our eyes immediately after viewing such objects, we shall still perceive a faint image of the object by the impression which its light has made upon our eyes.

"With respect to the *duration* of the impression of light, it has been observed that the teeth of a cog-wheel in a clock were still visible in succession, when the velocity of rotation brought 246 teeth through a given fixed point in a second. In this case it is clear that if the impression made on the eye by the light reflected from any tooth had lasted without sensible diminution for the 246th part of a second, the teeth would have formed one unbroken line, because a new tooth would have continually arrived in the place of the interior one before its image could have disappeared. If a live coal be whirled round, it is observed that the luminous circle is complete when the rotation is performed in the $\frac{8}{6}\frac{1}{0}$th part of a second. In this instance we see that the impression was much more durable than the former. Lastly, if an observer sitting in a room, direct his sight, through a window, to any particular object out of doors, for about half a minute, and then shut his eyes and cover them with his hands, he will still continue to see the window, together with the outline of the terrestrial objects bordering on the sky. This appearance will remain for near a minute, though occasionally vanishing and changing colour in a manner that brevity forbids our minutely describing. From these facts we are authorized to conclude that all impressions of light on the eye last a considerable time; that the brightest objects make the most lasting impressions; and that, if the object be very bright, or the eye weak, the impression may remain for a time so strong as to mix with and confuse the subsequent impressions made by other objects. In the last case the eye is said to be *dazzled* by the light."*

The following experiment has likewise been suggested as a proof the impression which light makes upon the eye: If a card, on both sides of which a figure is drawn, for example, a bird and a cage, be made to revolve rapidly on the straight line which divides it symmetrically, the eye will perceive both figures at the same time, provided they return successively at the same place. M. D'Arcy found by various experiments that, in general, the impression which light produces on the eye lasts about *the eighth of a second.* M. Plateau, of Brussels, found that the impression of different colours lasted the following periods, the numbers here stated being the decimal parts of a *second: flame,* 0.242, or nearly one-fourth of a second; *burning coal,* 0.229; *white,* 0.182, or a little more than one-sixth of a second; *blue,* 0.186; *yellow,* 0.173; *red,* 0.184.

5. *Light,* though extremely minute, *is supposed to have a certain degree of force or momentum.* In order to prove this, the late ingenius Mr. Mitchell contrived the following experiment: He constructed a small vane in the form of a common weathercock, of a *very thin* plate of copper, about an inch square, and attached to one of the finest harpsicord wires about ten inches long, and nicely balanced at the other end of the wire by a grain

*Nicholson's Introduction to Natural Philosophy, vol. I.

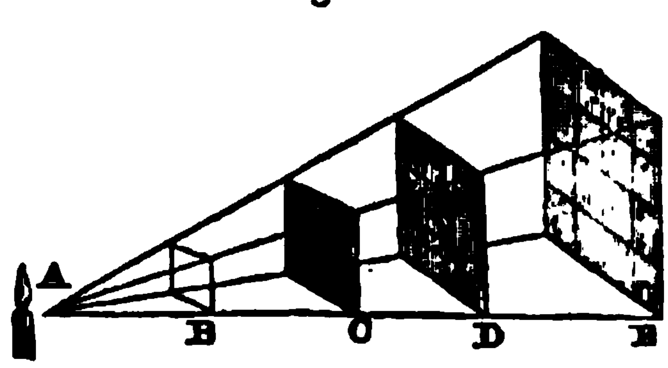
of very small shot. The instrument had also fixed to it in the middle, at right angles to the length of the wire, and in a horizontal direction, a small bit of a very slender sewing needle, about half an inch long, which was made magnetical. In this state the whole instrument might weigh about ten grains. The vane was supported in the manner of the needle in the mariner's compass, so that it could turn with the greatest ease; and to prevent its being affected by the vibrations of the air, it was inclosed in a glass case or box. The rays of the sun were then thrown upon the broad part of the vane, or copper plate, from a concave mirror of about two feet diameter, which, passing through the front glass of the box, were collected into the focus of the mirror upon the copper plate. In consequence of this, the plate began to move with a slow motion of about an inch in a second of time, till it had moved through a space of about two inches and a half, when it struck against the back of the box. The mirror being removed, the instrument returned to its former situation, and the rays of the sun being again thrown upon it, it again began to move, and struck against the back of the box as before. This was repeated three or four times with the same success.

On the above experiment the following calculation has been founded: if we impute the motion produced in this experiment to the impulse of the rays of light, and suppose that the instrument weighed ten grains, and acquired a velocity of one inch in a second, we shall find that the quantity of matter contained in the rays falling upon the instrument in that time amounted to no more than one twelve hundredth-millionth part of a grain, the velocity of light exceeding the velocity of one inch in a second in the proportion of about 12,000,000,000 to 1. The light in this experiment was collected from a surface of about three square feet, which reflecting only about half what falls upon it, the quantity of matter contained in the rays of the sun incident upon a foot and a half of surface in one second of time, ought to be no more than the twelve hundredth-millionth part of a grain. But the density of the rays of light at the surface of the sun is greater than that at the earth in the proportion of 45,000 to 1; there ought, therefore, to issue from one square foot of the sun's surface in one second of time, in order to supply the waste by light, $\frac{1}{45,000}$th part of a grain of matter, that is, a little more than two grains a day, or about 4,752,000 grains, or 670 pounds avoirdupois, nearly, in 6,000 years; a quantity which would have shortened the sun's diameter no more than about ten feet, if it were formed of the density of water only.

If the above experiment be considered as having been accurately performed, and if the calculations founded upon it be correct, it appears that there can be no grounds for apprehension that the sun can ever be sensibly diminished by the immense and incessant radiations proceeding from his body on the supposition that light is a material emanation. For the diameter of the sun is no less than 880,000 miles; and, before this diameter could be shortened, by the emission of light, one English mile, it would require three millions one hundred and sixty-eight thousand years, at the rate now stated; and, before it could be shortened ten miles, it would require a period of above thirty-one millions of years. And although the sun were thus actually diminished, it would produce no sensible effect or derangement throughout the planetary system. We have no reason to believe that the system, *in its present state and arrangements*, was intended to endure for ever; and before that luminary could be so far reduced, during the revolutions of eternity, as to produce any irregularities in the system, new arrangements and modifications might be introduced by the hand of the All Wise and Omnipotent Creator. Besides, it is not improbable that a system of means is established by which the sun and all the luminaries in the universe receive back again a portion of the light which they are continually emitting, either from the planets from whose surfaces it is reflected, or from the millions of stars whose rays are continually traversing the immense spaces of creation, or from some other sources to us unknown.

6. *The intensity of light is diminished in proportion to the square of the distance from the luminous body.* Thus, a person at two feet distance from a candle, has only the fourth part of the light he would have at one foot; at three feet distance, the ninth part; at four feet, the sixteenth part; at five feet, the twenty-fifth part; and so on for other distances. Hence the light received by the planets of the solar system decreases in proportion to the squares of the distances of these bodies from the sun. This may be illustrated be the following figure:

Fig. 1.




Suppose the light which flows from a point, A, and passes through a square hole, *B*, is re-

ceived upon a plane, $C$, parallel to the plane of the hole—or let the figure $C$ be considered as the shadow of the plane $B$. When the distance of $C$ is double of $B$, the length and breadth of the shadow, $C$, will be each double of the length and breadth of the plane $B$, and treble when $A\ D$ is treble of $A\ B$, and so on, which may be easily examined by the light of a candle placed at $A$. Therefore the surface of the shadow $C$, at the distance $A\ C$—double of $A\ B$, is divisible into four squares, and, at a treble distance, into nine squares, severally equal to the square $B$, as represented in the figure. The light, then, which falls upon the plane $B$ being suffered to pass to double that distance, will be uniformly spread over four times the space, and, consequently, will be four times thinner in every part of that space. And, at a treble distance, it will be nine times thinner, and, at a quadruple distance, sixteen times thinner than it was at first. Consequently, the quantities of this rarefied light received upon a surface of any given size and shape, when removed successively to their several distances, will be but one-fourth, one-ninth, one-sixteenth of the whole quantity received by it at the first distance, $A\ B$.

In conformity with this law, the relative quantities of light on the surfaces of the planets may be easily determined when their distances from the sun are known. Thus, the distance of Uranus from the sun is 1,800,-000,000 miles, which is about nineteen times greater than the distance of the earth from the same luminary. The square of 19 is 361; consequently, the earth enjoys 361 times the intensity of light, when compared with that of Uranus; in other words, this distant planet enjoys only the $\frac{1}{361}$ part of the quantity of light which falls upon the earth. This quantity, however, is equivalent to the light we should enjoy from the combined effulgence of 348 full moons; and if the pupils of the eyes of the inhabitants of this planet be much larger than ours, and the *retina* of the eye be endued with a much greater degree of nervous sensibility, they may perceive objects with as great a degree of splendour as we perceive on the objects which surround us in this world. Following out the same principle, we find that the quantity of light enjoyed by the planet Mercury is nearly *seven* times greater than that of the Earth, and that of Venus nearly *double* of what we enjoy; that Mars has less than the one-half; Jupiter the one-*twenty-seventh* part; and Saturn only the *one-ninetieth* part of the light which falls upon the Earth. That the light of these distant planets, however, is not so weak as we might at first imagine, appears from the brilliancy they exhibit, when viewed in our nocturnal sky, either with the telescope or with the unassisted eye; and likewise from the circumstance that a very small portion of the Sun—such as the one-fortieth or one-fiftieth part—diffuses a quantity of light sufficient for most of the purposes of life, as is found in the case of total eclipses of the Sun, when his western limb begins to be visible, only like a fine luminous thread, for his light is then sufficient to render distinctly visible all the parts of the surrounding landscape.

7. *It is by light reflected from opaque bodies that most of the objects around us are rendered visible.* When a lighted candle is brought into a dark room, not only the candle, but all other bodies in the room become visible. Rays of the sun, passing into a dark room, render luminous a sheet of paper on which they fall, and this sheet, in its turn, enlightens, to a certain extent, the whole apartment, and renders objects in it visible so long as it receives the rays of the sun. In like manner, the moon and the planets are opaque bodies, but the light of the sun falling upon them, and being reflected from their surfaces, renders them visible. Were no light to fall on them from the sun, or were they not endued with a power of reflecting it, they would be altogether invisible to our sight. When the moon comes between us and the sun, as in a total eclipse of that luminary, as no solar light is reflected from the surface next the earth, she is invisible, only the curve or outline of her figure being distinguished by her shadow. In this case, however, there is a certain portion of reflected light on the lunar hemisphere next the earth, though not distinguishable during a solar eclipse. The earth is enlightened by the sun, and a portion of the rays which fall upon it is reflected upon the dark hemisphere of the moon which is then towards the earth. This reflected light from the earth is distinctly perceptible, when the moon appears as a slender crescent, two or three days after new moon—when the earth reflects its light back on the moon, in the same manner as the full moon reflects her light on the earth. Hence, even at this period of the moon, her whole face becomes visible to us, but its light is not uniform or of equal intensity. The thin crescent on which the full blaze of the solar light falls, is very brilliant and distinctly seen, while the other part, on which falls only a comparatively feeble light from the earth, appears very faint, and is little more than visible to the naked eye, but with a telescope of moderate power—if the atmosphere be very clear—it appears beautifully distinct, so that the relative positions of many of the lunar spots may be distinguished.

The intensity of reflected light is very

small, when compared with that which proceeds directly from luminous bodies. M. Bouguer, a French philosopher, who made a variety of experiments to ascertain the proportion of light emitted by the heavenly bodies, concluded, from these experiments, that the light transmitted from the sun to the earth is at least 300,000 times as great as that which descends to us from the full moon, and that, of 300,000 rays which the moon receives, from 170,000 to 200,000 are absorbed. Hence we find that, however brilliant the moon may appear at night, in the daytime she appears as obscure as a small portion of dusky cloud to which she happens to be adjacent, and reflects no more light than a portion of whitish cloud of the same size. And as the full moon fills only the ninety-thousandth part of the sky, it would require at least ninety thousand moons to produce as much light as we enjoy in the daytime under a cloudy sky.

As the moon and the planets are rendered visible to us only by light reflected from their surfaces, so it is in the same way that the images of most of the objects around us are conveyed to our organs of vision. We behold all the objects which compose an extensive landscape—the hills and vales, the woods and lawns, the lakes and rivers, and the habitations of man—in consequence of the capacity with which they are endued of sending forth reflected rays to the eye, from every point of their surfaces and in all directions. In connexion with the reflection of light, the following curious observation may be stated: Baron Funk, visiting some silver mines in Sweden, observed, that, "in a clear day, it was as dark as pitch under ground in the eye of a pit, at sixty or seventy fathoms deep; whereas, in a cloudy or rainy day, he could see to read even at 106 fathoms deep. Inquiring of the miners, he was informed that this is always the case; and reflecting upon it, he imagined it arose from this circumstance, that, when the atmosphere is full of clouds, light is reflected from them into the pit in all directions, and that thereby a considerable proportion of the rays are reflected perpendicularly upon the earth: whereas, when the atmosphere is clear, there are no opaque bodies to reflect the light in this manner, at least in a sufficient quantity; and rays from the sun himself can never fall perpendicularly in that country." The reason here assigned is, in all probability, the true cause of the phenomenon now described.

8. It is supposed by some philosophers that *light is subject to the same laws of attraction that govern all other material substances,* and that *it is imbibed and forms a constituent part of certain bodies.* This has been inferred from the phenomena of the *Bolognian stone,* and what are generally called the *solar phosphori.* The Bolognian stone was first discovered about the year 1630, by Leascariolo, a shoemaker of Bologna. Having collected together some stones of a shining appearance at the bottom of Monte Paterno, and being in quest of some alchemical secret, he put them into a crucible to calcine them; that is, to reduce them to the state of cinders. Having taken them out of the crucible, and exposed them to the light of the sun, he afterward happened to carry them into a dark place, when, to his surprise, he observed that they possessed a self-illuminating power, and continued to emit faint rays of light for some hours afterward. In consequence of this discovery, the Bolognian spar came into considerable demand among natural philosophers, and the curious in general; and the best way of preparing it seems to have been hit upon by the family of Zagoni, who supplied all Europe with Bolognian phosphorus till the discovery of more powerful phosphoric substances put an end to their monopoly. In the year 1677, Baldwin, a native of Misnia, observed that chalk, dissolved in aquafortis, exactly resembled the Bolognian stone in its property of imbibing light, and emitting it after it was brought into the dark; and hence it has obtained the name of Baldwin's phosphorus.

In 1730 M. Du Fay directed his attention to this subject, and observed that all earthy substances susceptible of calcination, either by mere fire, or when assisted by the previous action of nitrous acid, possessed the property of becoming more or less luminous, when calcined and exposed for a short time in the light; that the most perfect of these phosphori were limestones, and other kinds of carbonated lime, gypsum, and particularly the topaz, and that some diamonds were also observed to be luminous by simple exposure to the sun's rays. Some time afterward Beccaria discovered that a great variety of other bodies were convertible into phosphori by exposure to the mere light of the sun, such as organic animal remains, most compound salts, nitre and borax—all the farinaceous and oily seeds of vegetable substances, all the gums and several of the resins—the white woods and vegetable fibre, either in the form of paper or linen; also starch and loaf-sugar proved to be good phosphori, after being made thoroughly dry, and exposed to the direct rays of the sun. Certain animal substances by a similar treatment were also converted into phosphori; particularly bone, sinew, glue, hair, horn, hoof, feathers, and fish-shells. The same property was communicated to rock crystal

and some other of the gems, by rubbing them against each other so as to roughen their surfaces, and then placing them for some minutes in the focus of a lens, by which the rays of light were concentrated upon them at the same time that they were also moderately heated.

In the year 1768 Mr. Canton contributed some important facts in relation to solar phosphori, and communicated a method of preparing a very powerful one, which, after the inventor, is usually called *Canton's phosphorus*. He affirms that his phosphorus, inclosed in a glass flask, and hermetically sealed, retains its property of becoming luminous for at least four years, without any apparent decrease of activity. It has also been found that, if a common box smoothing-iron, heated in the usual manner, be placed for half a minute on a sheet of dry, white paper, and the paper be then exposed to the light, and afterward examined in a dark closet, it will be found that the whole paper will be luminous, that part, however, on which the iron had stood being much more shining than the rest.

From the above facts it would seem that certain bodies have the power of imbibing light and again emitting it, in certain circumstances, and that this power may remain for a considerable length of time. It is observed that the light which such bodies emit bears an analogy to that which they have imbibed. In general, the illuminated phosphorus is reddish; but when a weak light only has been admitted to it, or when it has been received through pieces of white paper, the emitted light is pale or whitish. Mr. Morgan, in the seventy-fifth volume of the Philosophical Transactions, treats the subject of light at considerable length; and as a foundation for his reasoning, he assumes the following data: 1. That light is a body, and, like all others, subject to the laws of attraction. 2. That light is a heterogeneous body, and that the same attractive power operates with different degrees of force on its different parts. To the principle of attraction, likewise, Sir Isaac Newton has referred the most extraordinary phenomena of light, Refraction and Inflection. He has also endeavoured to show that light is not only subject to the law of attraction, but of repulsion also, since it is repelled or reflected from certain bodies. If such principles be admitted, then it is highly probable that the phosphorescent bodies to which we have adverted have a power of attracting or imbibing the substance of light, and of retaining or giving it out under certain circumstances, and that the matter of light is incorporated, at least, with the surface of such bodies; but on this subject, as on many others, there is a difference of opinion among philosophers.*

9. *Light is found to produce a remarkable effect on plants and flowers, and other vegetable productions.* Of all the phenomena which living vegetables exhibit, there are few that appear more extraordinary than the energy and constancy with which their stems incline towards the light. Most of the discous flowers follow the sun in his course. They attend him to his evening retreat, and meet his rising lustre in the morning with the same unerring law. They unfold their flowers on the approach of this luminary; they follow his course by turning on their stems, and close them as soon as he disappears. If a plant, also, is shut up in a dark room, and a small hole afterward opened by which the light of the sun may enter, the plant will turn towards that hole, and even alter its own shape in order to get near it; so that though it was straight before, it will in time become crooked, that it may get near the light. Vegetables placed in rooms where they receive light only in one direction, always extend themselves in that direction. If they receive light in two directions, they direct their course towards that which is strongest. It is not the *heat*, but the *light* of the sun

* Light of a phosphoric nature is frequently emitted from various putrescent animal substances, which, in the ages of superstition, served to astonish and affright the timorous. We learn from Fabricius, an Italian, that three young men, residing at Padua, having bought a lamb, and eaten part of it on Easter Day, 1592, several pieces of the remainder, which they kept till the following day, shone like so many candles when they were casually viewed in the dark. The astonishment of the whole city was excited by this phenomenon, and a part of the flesh was sent to Fabricius, who was professor of anatomy, to be examined by him. He observed that those parts which were soft to the touch and transparent in candle-light were the most resplendent; and also that some pieces of kid's flesh which had happened to have lain in contact with them were luminous, as well as the fingers and other parts of the bodies of those persons who touched them. Bartholin gives an account of a similar phenomenon, which happened in Montpelier, in 1641. A poor woman had bought a piece of flesh in the market, intending to make use of it on the following day; but happening not to be able to sleep well that night, and her bed and pantry being in the same room, she observed so much light come from the flesh as to illuminate all the place where it hung. We may judge of the terror and astonishment of the woman herself, when we find that a part of this luminous flesh was carried as a very extraordinary curiosity to Henry, duke of Conde, the governor of the place, who viewed it several hours with the greatest astonishment. The light was as if gems had been scattered over the surface, and continued till the flesh began to putrefy, when it vanished, which it was believed to do in the form of a cross. Hence the propriety of instructing the mass of the community in the knowledge of the facts connected with the material system, and the physical causes of the various phenomena of nature.

which the plant thus covets; for, though a fire be kept in the room, capable of giving a much stronger heat than the sun, the plant will turn away from the fire in order to enjoy the solar light. Trees growing in thick forests, where they only receive light from above, direct their shoots almost invariably upward, and therefore become much taller and less spreading than such as stand single.

The *green* colour of plants is likewise found to depend on the sun's light being allowed to shine on them; for without the influence of the solar light they are always of a *white* colour. It is found by experiment that, if a plant which has been reared in darkness be exposed to the light of day, in two or three days it will acquire a green colour perceptibly similar to that of plants which have grown in open daylight. If we expose to the light one part of the plant, whether leaf or branch, this part alone will become green. If we cover any part of a leaf with an opaque substance, this place will remain white, while the rest becomes green. The whiteness of the inner leaves of cabbages is a partial effect of the same cause, and many other examples of the same kind might easily be produced. M. Decandolle, who seems to have paid particular attention to this subject, has the following remarks: "It is certain, that between the white state of plants vegetating in darkness, and complete verdure, every possible intermediate degree exists, determined by the intensity of the light. Of this any one may easily satisfy himself by attending to the colour of a plant exposed to the full daylight; it exhibits in succession all the degrees of verdure. I had already seen the same phenomenon, in a particular manner, by exposing plants reared in darkness to the light of lamps. In these experiments, I not only saw the colour come on gradually, according to the continuance of the exposure to light, but I satisfied myself that a certain intensity of permanent light never gives to a plant more than a certain degree of colour. The same fact readily shows itself in nature, when we examine the plants that grow under shelter or in forests, or when we examine in succession the state of the leaves that form the heads of cabbages."*

It is likewise found that the *perspiration* of vegetables is increased or diminished in a certain measure by the degree of *light* which falls upon them. The experiments of Mr. P. Miller and others prove that plants uniformly perspire most in the forenoon, though the temperature of the air in which they are placed should be unvaried. M. Guettard likewise informs us that a plant exposed to the rays of the sun has its perspiration increased to a much greater degree than if it had been exposed to the same heat under the shade. Vegetables are likewise found to be indebted to light for their smell, taste, combustibility, maturity, and the resinous principle, which equally depend upon this fluid. The aromatic substances, resins, and volatile oil are the productions of southern climates, where the light is more pure, constant, and intense. In fine, another remarkable property of light on the vegetable kingdom is that, when vegetables are exposed to open daylight, or to the sun's rays, they emit oxygen gas, or vital air. It has been proved that, in the production of this effect, the sun does not act as a body that heats. The emission of the gas is determined by the light: pure air is therefore separated by the action of light, and the operation is stronger as the light is more vivid. By this continual emission of vital air, the Almighty incessantly purifies the atmosphere, and repairs the loss of pure air occasioned by respiration, combustion, fermentation, putrefaction, and numerous other processes which have a tendency to contaminate this fluid, so essential to the vigour and comfort of animal life; so that, in this way, by the agency of light, a due equilibrium is always maintained between the constituent parts of the atmosphere.

In connexion with this subject the following curious phenomenon may be stated, as related by M. Haggern, a lecturer on Natural History in Sweden. One evening he perceived a faint flash of light repeatedly dart from a marigold. Surprised at such an uncommon appearance, he resolved to examine it with attention; and, to be assured it was no deception of the eye, he placed a man near him, with orders to make a signal at the moment when he observed the light. They both saw it constantly at the same moment. The light was most brilliant on marigolds of an orange or flame colour, but scarcely visible on pale ones. The flash was frequently seen on the same flower two or three times in quick succession, but more commonly at intervals of several minutes; and when several flowers in the same place emitted their light together, it could be observed at a considerable distance. The phenomenon was remarked in the months of July and August at sunset, and for half an hour when the atmosphere was clear; but after a rainy day, or when the air was loaded with vapours, nothing of it was seen. The following flowers emitted flashes more or less vivid, in this order: 1. The Marigold. 2. Monk's Hood. 3. The Orange Lily. 4. The Indian Pink. As to the *cause* of this phenomenon, different opinions may be entertained. From the rapidity of the flash and other circumstances, it may

* Memoires de la Soc. d'Arcueil. vol. ii.

be conjectured that electricity is concerned in producing this appearance. M. Haggern, after having observed the flash from the orange lily, the antheræ of which are at considerable distance from the petals, found that the light proceeded from the petals only; whence he concludes that this electrical light is caused, by the pollen, which, in flying off, is scattered on the petals. But, perhaps, the true cause of it still remains to be ascertained.

10. *Light has been supposed to produce a certain degree of influence on the* PROPAGATION OF SOUND. M. Parolette, in a long paper in the "Journal de Physique," vol. 68, which is copied into "Nicholson's Philosophical Journal," vol. 25, p. 28–39, has offered a variety of remarks, and detailed a number of experiments on this subject. The author states the following circumstances as having suggested the connexion between light and sound: "In 1803 I lived in Paris, and being accustomed to rise before day to finish a work on which I had long been employed, I found myself frequently disturbed by the sound of carriages, as my windows looked into one of the most frequented streets in that city. This circumstance, which disturbed me in my studies every morning, led me to remark that the appearance of daybreak peculiarly affected the propagation of the sound; from dull and deep, which it was before day, it seemed to me to acquire a more sonorous sharpness in the period that succeeded the dissipation of darkness. The rolling of the wheels seemed to announce the friction of some substances grown more elastic; and my ear, on attending to it, perceived this difference diminish in proportion as the sound of wheels was confounded with those excited by the tumult of objects quitting their nocturnal silence. Struck with this observation, I attempted to discover whether any particular causes had deceived my ears. I rose several times before day for this purpose alone, and was every time confirmed in my suspicion that light must have a peculiar influence on the propagation of sound. This variation, however, in the manner in which the air gave sounds, might be the effect of the agitation of the atmosphere produced by the rarefaction the presence of the sun occasioned; but the situation of my windows, and the usual direction of the morning breeze, militated against this argument."

The author then proceeds to give a description of a very delicate instrument, and various apparatus for measuring the propagation and intensity of sound, and the various experiments both in the dark and in daylight, and likewise under different changes of the atmosphere, which were made with his apparatus, all of which tended to prove that light had a sensible influence in the propagation of sound. But the detail of these experiments and their several results would be too tedious to be here transcribed. The night has generally been considered as more favourable than the day for the transmission of sound. "That this is the case," says Parolette, "with respect to our ears cannot be doubted: but this argues nothing against my opinion. We hear further by night on account of the silence, and this always contributes to it, while the noise of a wind favourable to the propagation of a sound may prevent the sound from being heard." In reference to the cause which produces the effect now stated, he proposes the following queries: "Is the atmospheric air more dense on the appearance of light than in darkness? Is this greater density of the air, or of the elastic fluid that is subservient to the propagation of sound, the effect of aeriform substances kept in this state through the medium of light?" He is disposed, on the whole, to conclude that the effect in question is owing to the action of light upon the oxygen of the atmosphere, since oxygen gas is found by experiment to be best adapted to the transmission of sound.

Our author concludes his communication with the following remarks: "Light has a velocity 900,000 times as rapid as that of sound. Whether it emanate from the sun and reach to our earth, or act by means of vibrations agitating the particles of a fluid of a peculiar nature, the particles of this fluid must be extremely light, elastic, and active. Nor does it appear to me unreasonable to ascribe to the mechanical action of these particles set in motion by sun the effects its presence occasions in the vibrations that proceed from sonorous bodies. The more deeply we investigate the theory of light, the more we must perceive that the powers by which the universe is moved reside in the imperceptible particles of bodies; and that the grand results of nature are but an assemblage of an order of actions that take place in its infinitely small parts; consequently, we cannot institute a series of experiments more interesting than those which tend to develope the properties of light. Our organs of sense are so immediately connected with the fluid that enlightens us, that a notion of having acquired an idea of the mode of action of this fluid presents itself to our minds, as the hope of a striking advance in the knowledge of what composes the organic mechanism of our life, and of that of beings which closely follow the rank assigned to the human species."

Such is a brief description of some of the leading properties of light. Of all the objects that present themselves to the philosophic and contemplative mind, light is one of the noblest and most interesting. The action it exerts

on all the combinations of matter, its extreme divisibility, the rapidity of its propagation, the sublime wonders it reveals, and the office it performs in what constitutes the life of organic beings, lead us to consider it as a substance acting the first part in the economy of nature. The magic power which this emanation from the heavens exerts on our organs of vision, in exhibiting to our view the sublime spectacle of the universe, cannot be sufficiently admired. Nor is its power confined to the organs of sight; all our senses are, in a greater or less degree, subjected to the action of light, and all the objects in this lower creation—whether in the animal, the vegetable, or the mineral kingdoms—are, to a certain extent, susceptible of its influence. Our globe appears to be little more than an accumulation of terrestrial materials introduced into the boundless ocean of the *solar light*, as a theatre on which it may display its exhaustless power and energy, and give animation, beauty, and sublimity to every surrounding scene, and to regulate all the powers of nature, and render them subservient to the purposes for which they were ordained. This elementary substance appears to be universal in its movements and in its influence. It descends to us from the solar orb. It wings its way through the voids of space, along a course of ninety-five millions of miles, till it arrives at the outskirts of our globe; it passes freely through the surrounding atmosphere; it strikes upon the clouds, and is reflected by them; it irradiates the mountains, the vales, the forests, the rivers, the seas, and all the productions of the vegetable kingdom, and adorns them with a countless assemblage of colours. It scatters and disperses its rays from one end of creation to another, diffusing itself throughout every sphere of the universe. It flies without intermission from star to star, and from suns to planets, throughout the boundless sphere of immensity, forming a connecting chain and a medium of communication among all the worlds and beings within the wide empire of Omnipotence.

When the sun is said "to rule over the day," it is intimated that he acts as the vicegerent of the Almighty, who has invested him with a mechanical power of giving light, life, and motion to all the beings susceptible of receiving impressions from his radiance. As the servant of his Creator, he distributes blessings without number among all the tribes of sentient and intelligent existence. When his rays illumine the eastern sky in the morning, all nature is enlivened with his presence. When he sinks beneath the western horizon, the flowers droop, the birds retire to their nests, and a mantle of darkness is spread over the landscape of the world. When he approaches the equinox in spring, the animal and vegetable tribes revive and nature puts on a new and a smiling aspect When he declines towards the winter solstice, dreariness and desolation ensue, and a temporary death takes place among the tribes of the vegetable world. This splendid luminary, whose light embellishes the whole of this lower creation, forms the most lively representation of Him who is the source and the centre of all beauty and perfection. "God is a sun," the sun of the moral and spiritual universe, from whom all the emanations of knowledge, love, and felicity descend. "He covereth himself with light as with a garment," and "dwells in light inaccessible and full of glory." The felicity and enjoyments of the future world are adumbrated under the ideas of *light* and *glory*. "The glory of God enlightens the celestial city;" its inhabitants are represented as "the saints *in light*;" it is declared that "their *sun* shall no more go down," and that "the Lord God is their *everlasting light*." So that light not only cheers and enlivens all beings throughout the material creation, but is the emblem of the Eternal Mind, and of all that is delightful and transporting in the scenes of a blessed immortality.

In the formation of light, and the beneficent effects it produces, the wisdom and goodness of the Almighty are conspicuously displayed. Without the beams of the sun and the influence of light, what were all the realms of this world but an undistinguished chaos and so many dungeons of darkness? In vain should we roll our eyes around to behold, amid the universal gloom, the flowery fields, the verdant plains, the flowing streams, the expansive ocean, the moon walking in brightness, the planets in their courses, or the innumerable host of stars. All would be lost to the eye of man, and the "blackness of darkness" would surround him for ever. And with how much wisdom has every thing been arranged in relation to the motions and minuteness of light? Were it capable of being transformed into a solid substance, and retain its present velocity, it would form the most dreadful and appalling element in nature, and produce universal terror and destruction throughout the universe. That this is not impossible, and could easily be effected by the hand of Omnipotence, appears from such substances as *phosphorus*, where light is supposed to be concentrated in a solid state. But in all its operations and effects, as it is now directed by unerring wisdom and beneficence, it exhibits itself as the most benign and delightful element connected with the constitution of the material system, diffusing splendour and felicity wherever its influence extends.

## CHAPTER V.

### *On the Refraction of Light.*

Refraction is the turning or bending of the rays of light out of their natural course.

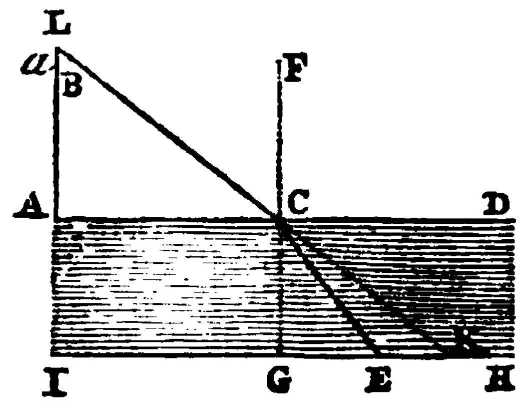
Light, when proceeding from a luminous body—without being reflected from any opaque substance or inflected by passing near one—is invariably found to proceed in straight lines without the least deviation. But if it happens to pass obliquely from one medium to another, it always leaves the direction it had before and assumes a new one. This change of direction, or *bending* of the rays of light, is what is called *Refraction*—a term which probably had its origin from the broken appearance which a staff or a long pole exhibits when a portion of it is immersed in water—the word, derived from the Latin *frango*, literally signifying *breaking* or bending.

When light is thus refracted, or has taken a new direction, it then proceeds invariably in a straight line till it meets with a different medium,* when it is again turned out of its course. It must be observed, however, that though we may by this means cause the rays of light to make any number of angles in their course, it is impossible for us to make them describe a curve, except in one single case, namely, where they pass through a medium, the density of which either uniformly increases or diminishes. This is the case with the light of the celestial bodies, which passes downward through our atmosphere, and likewise with that which is reflected upward through it by terrestrial objects. In both these cases it describes a curve of the hyperbolic kind; but at all other times it proceeds in straight lines, or in what may be taken for straight lines without any sensible error.

There are two circumstances essential to refraction. 1. That the rays of light shall pass out of one medium into another of a different density, or of a greater or less degree of resistance. 2. That they pass in an *oblique* direction. The denser the refracting medium, or that into which the ray enters, the greater will be its refracting power; and of two refracting mediums of the same density, that which is of an oily or inflammable nature will have a greater refracting power than the other. The nature of refraction may be more particularly explained and illustrated by the following figure and description:

Let $A\ D\ H\ I$, fig. 2, be a body of water, $A\ D$ its surface, $C$ a point in which a ray of light, $B\ C$, enters from the air into the water. This ray, by the greater density of the water, instead of passing straight forward in its first direction to $K$, will be bent at the point $C$, and pass along in the direction $C\ E$, which is called the *refracted* ray.

Fig. 2.




Let the line $F\ G$ be drawn perpendicular to the surface of the water in $C$, then it is evident that the ray $B\ C$, in passing out of air, a *rare* medium, into a *dense* medium, as water, is refracted into a ray $C\ E$, which is *nearer* to the perpendicular $C\ G$ than the incident ray $B\ C$, and, on the contrary, the ray $E\ C$, passing out of a denser medium into a rarer, will be refracted into $C\ B$, which is *further* from the perpendicular.

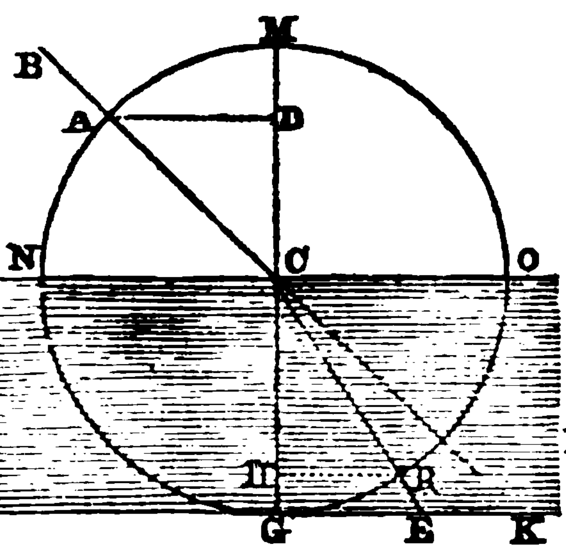
The same thing may be otherwise illustrated as follows: Suppose a hole made in one of the sides of the vessel, as at $a$, and a lighted candle placed within two or three feet of it, when empty, so that its flame may be at $L$, a ray of light proceeding from it will pass through the hole, $a$, in a straight line, $L\ B\ C\ K$, till it reach the bottom of the vessel at $K$, where it will form a small circle of light. Having put a mark at the point $K$, pour water into the vessel till it rise to the height $A\ D$, and the round spot that was formerly at $K$ will appear at $E$; that is, the ray which went straight forward, when the vessel was empty, to $K$, has been bent at the point $C$, where it falls into the water, into the line $C\ E$. In this experiment it is necessary that the front of the vessel should be of glass, in order that the course of the ray may be seen; and if a little soap be mixed with the water so as to give it a little mistiness, the ray $C\ E$ will be distinctly perceived. If, in place of fresh water, we pour in salt water, it will be

* By a *medium*, in optics, is meant the space in which a ray of light moves, whether pure space, air, water, glass, diamond, or any other transparent substance through which the rays of light can pass in straight lines.

found that the ray $B\ C$ is more bent at $C$. In like manner, alcohol will refract the ray $B\ C$ more than salt water, and oil more than alcohol, and a piece of solid glass, of the shape of the water, would refract the light still more than the oil.

The angle of refraction depends on the obliquity of the rays falling on the refracting surface being always such, that the sine of the incident angle is to the sine of the refracted angle in a given proportion. The *incident* angle is the angle made by a ray of light and a line drawn perpendicular to the refracting surface, at the point where the light enters the surface. The *refracted* angle is the angle made by the ray in the refracting medium with the same perpendicular produced. The *sine* of the angle is a line which serves to measure the angle, being drawn from a point in one leg perpendicular to the other. The following figure (fig. 3) will tend to illustrate these definitions.

Fig. 3.




In this figure, $B\ C$ is the incident ray, $C\ E$ the refracted ray, $D\ G$ the perpendicular, $A\ D$ the sine of the angle of incidence $A\ C\ D$, and $H\ R$ the sine of the angle of refraction $G\ C\ E$. Now, it is a proposition in optics, that the sine $A\ D$ of the angle of incidence $B\ C\ D$ is either accurately or very nearly in a given proportion to the sine $H\ R$ of the angle of refraction $G\ C\ E$. This ratio of the sines is as four to three, when the refraction is made out of air into water, that is, $A\ D$ is to $H\ R$ as four to three. When the refraction is out of air into glass, the proportion is about as thirty-one to twenty, or nearly as three to two. If the refraction be out of air into diamond, it is as five to two, that is $A\ D : H\ R : : 5 : 2$. The denser the medium is, the less is the angle and sine of refraction. If a ray of light, $M\ C$, were to pass from air into water, or from empty space into air, in the direction $M\ C$ perpendicular to the plane $N\ O$, which separates the two mediums, it would suffer no refraction, because one of the essentials to that effect is wanting, namely, the *obliquity* of the incidence.

It may also be proper to remark that a ray of light cannot pass out of a denser medium into a rarer, if the angle of incidence exceed a certain limit. Thus a ray of light will not pass out of glass into air, if the angle of incidence exceed $40° 11'$; or out of glass into water, if the angle of incidence exceed $59° 20'$. In such cases refraction will be changed into reflection.

The following common experiments, which are easily performed, will illustrate the doctrine of refraction: Put a shilling, or any other small object which is easily distinguished, into a basin or any other similar vessel, and then retire to such a distance as that the edge of the vessel shall just hide it from your sight. If then you cause another person to fill the vessel with water, you will find that the shilling is rendered perfectly visible, although you have not in the slightest degree changed your position. The reason of this is, that the rays of light, by which it is rendered visible *are bent out of their course*. Thus, suppose the shilling to have been placed in the bottom of the basin at $E$ (fig. 2,) the ray of light $B\ C$ which passes obliquely from the air into water at $C$, instead of continuing its course to $K$, takes the direction of $C\ E$, and, consequently, an object at $E$ would be rendered visible by rays proceeding in that direction, when they would not have touched it had they proceeded in their direct course.

The same principle is illustrated by the following experiment: Place a basin or square box on a table, and a candle at a small distance from it; lay a small rod or stick across the sides of the basin, and mark the place where the extremity of the shadow falls, by placing a shilling or other object at the point; then let water be poured into the basin, and the shadow will then fall much nearer to the side next the candle than before. This experiment may likewise be performed by simply observing the change produced on the shadow of the side of the basin itself. Again, put a long stick obliquely into deep water, and the stick will seem to be broken at the point where it appears at the surface of the water, the part which is immersed in the water appearing to be bent upward. Hence every one must have observed that, in rowing a boat, the ends of the oars appear bent or broken every time they are immersed in the water, and their appearance at such times is a representation of the course of the refracted rays. Again, fill a pretty deep jar with water, and you will observe the bottom of the jar considerably elevated, so that it appears much shallower than it did before the water was poured in, in the proportion of nearly a third

of its depth, which is owing to the same cause as that which makes the end of a stick immersed in water appear more elevated than it would do if there were no refraction. Another experiment may be just mentioned. Put a sixpence in a wine-glass, and pour upon it a little water. When viewed in a certain position, two sixpences will appear in the glass—one image of the sixpence from below, which comes directly to the eye, and another which appears considerably raised above the other, in consequence of the rays of light rising through the water, and being refracted. In this experiment the wine-glass should not be more than half filled with water.

The refraction of light explains the causes of many curious and interesting phenomena both in the heavens and on the earth. When we stand on the banks of a river, and look obliquely through the waters to its bottom, we are apt to think it is much shallower than it really is. If it be eight feet deep in reality, it will appear from the bank to be only six feet; if it be five feet and a half deep, it will appear only about four feet. This is owing to the effects of refraction, by which the bottom of the river is apparently raised by the refraction of the light passing through the water into air, so as to make the bottom appear higher than it really is, as in the experiment with the jar of water. This is a circumstance of some importance to be known and attended to in order to personal safety; for many schoolboys and other young persons have lost their lives by attempting to ford a river, the bottom of which appeared to be within their reach when they viewed it from its banks; and even adult travellers on horseback have sometimes fallen victims to this optical deception; and this is not the only case in which a knowledge of the laws of nature may be useful in guarding us against dangers and fatal accidents.

It is likewise owing to this refractive power in water that a skilful marksman, who wishes to shoot fish under water, is obliged to take aim considerably *below* the fish as it appears, because it seems much nearer the top of the water than it really is. An acquaintance with this property of light is particularly useful to divers, for, in any of their movements or operations, should they aim directly at the object, they would arrive at a point considerably beyond it; whereas, by having some idea of the depth of the water, and the angle which a line drawn from the eye to the object makes with its surface, the point at the bottom of the water, between the eye and the object at which the aim is to be taken, may be easily determined. For the same reason, a person below water does not see objects distinctly. For, as the aqueous humour of the eye has the same refractive power as water, the rays of light from any object under water will undergo no refraction in passing through the cornea and aqueous humour, and will therefore meet in a point far behind the retina. But if any person, accustomed to go below water, should use a pair of spectacles, consisting of two convex lenses, the radius of whose surface is three tenths of an inch—which is nearly the radius of the convexity of the cornea—he will see objects as distinctly below water as above it.

It is owing to refraction that we cannot judge so accurately of magnitudes and distances in water as in air. A fish looks considerably larger in water than when taken out of it. An object plunged *vertically* into water always appears contracted, and the more so as its upper extremity approaches nearer the surface of the water. Every thing remaining in the same situation, if we take the object gradually out of the water, and it be of a slender form, we shall see it become larger and larger, by a rapid developement, as it were, of all its parts. The distortion of objects, seen through a crooked pane of glass in a window, likewise arises from its unequal refraction of the rays that pass through it. It has been calculated that, in looking through the common glass of a window, objects appear about the one-thirtieth of an inch out of their real place, by means of the refraction.

Refraction likewise produces an effect upon the *heavenly bodies*, so that their apparent positions are generally different from their real. By the refractive power of the atmosphere, the sun is seen before he comes to the horizon in the morning, and after he sinks beneath it in the evening; and hence this luminary is never seen in the place in which it really is, except when it passes the zenith at noon, to places within the torrid zone. The sun is visible when actually thirty-two minutes of a degree below the horizon, and when the opaque rotundity of the earth is interposed between our eye and that orb, just on the same principle as, in the experiment with the shilling and basin of water, the shilling was seen when the edge of the basin interposed between it and the sight. The refractive power of the atmosphere has been found to be much greater, in certain cases, than what has been now stated. In the year 1595, a company of Dutch sailors having been wrecked on the shores of Nova Zembla, and having been obliged to remain in that desolate region during a night of more than three months, beheld the sun make his appearance in the horizon about sixteen days before the time in which he should have risen according to calculation, and when his body was actually more than four degrees below the horizon;

which circumstance has been attributed to the great refractive power of the atmosphere in those intensely cold regions. This refraction of the atmosphere, which renders the apparent rising and setting of the sun both earlier and later than the real, produces, at least, one important beneficial effect. It procures for us the benefit of a much longer day, at all seasons of the year, than we should enjoy did not this property of the atmosphere produce this effect. It is owing to the same cause that the disks of the sun and moon appear elliptical or oval when seen in the horizon, their horizontal diameters appearing longer than their vertical, which is caused by the greater refraction of the rays coming from the lower limb, which is immersed in the densest part of the atmosphere.

The illumination of the heavens which precedes the rising of the sun, and continues some time after he is set, or what is commonly called the morning and evening *twilight*, is likewise produced by the atmospherical refraction, which circumstance forms a very pleasing and beneficial arrangement in the system of nature. It not only prolongs to us the influence of the solar light, and adds nearly two hours to the length of our day, but prevents us from being transported all at once from the darkness of midnight to the splendour of noonday, and from the effulgence of day to the gloom and horrors of the night, which would bewilder the traveller and navigator in their journeys by sea or land, and strike the living world with terror and amazement.

The following figure will illustrate the position now stated, and the manner in which the refraction of the atmosphere produces these effects: Let *A a C*, fig. 4, represent one-half of our globe, and the dark space between that curve and *B r D*, the atmosphere. A person standing on the earth's surface at *a* would see the sun rise at *b*, when that luminary was in reality only at *c*, more than half

Fig. 4.

a degree below the horizon. When the rays of the sun, after having proceeded in a straight line through empty space, strike the upper part of the atmosphere at the point *d*, they are bent out of their right-lined course by the refraction of the atmosphere, into the direction *d a*, so that the body of the sun, though actually intercepted by the curve of the earth's convexity, consisting of a dense mass of land or water, is actually beheld by the spectator at *a*. The refractive power of the atmosphere gradually diminishes from the horizon to the zenith, and increases from the zenith to the horizon, in proportion to the density of its different strata, being densest at its lower extremity next the earth, and more rare towards its higher regions. If a person at *a* had the sun, *e*, in his zenith, he would see him where he really is; for his rays coming perpendicularly through the atmosphere, would be equally attracted in all directions, and would, therefore, suffer no inflection. But, about two in the afternoon, he would see the sun at *i*, though, in reality, he was at *k*, thirty-three seconds lower than his apparent situation. At about four in the afternoon he would see him at *m*, when he is at *n*, one minute and thirty-eight seconds from his apparent situation. But at six o'clock, when we shall suppose he sets, he will be seen at *o*, though he is at that time at *p*, more than thirty-two minutes below the horizon. These phenomena arise from the different refractive powers of the atmosphere at different elevations, and from the obliquity with which the rays of light fall upon it; for we see every object along that line in which the rays from it are directed by the last medium through which they passed.

The same phenomena happen in relation to the moon, the planets, the comets, the stars, and every other celestial body, all of which appear more elevated, especially when near the horizon, than their true places. The variable and increasing refraction from the zenith to the horizon is a source of considerable trouble and difficulty in making astronomical observations, and in nautical calculations; for, in order to determine the real altitudes of the heavenly bodies, the exact degree of refraction at the observed elevation must be taken into account. To the same cause we are to ascribe a phenomenon that has sometimes occurred, namely, that the moon has been seen rising totally eclipsed, while the sun was still visible in the opposite quarter of the horizon. At the middle of a total eclipse of the moon, the sun and moon are in opposition, or 180 degrees asunder; and, therefore, were no atmosphere surrounding the earth, these luminaries, in such a position, could never be seen above the horizon at the same time. But, by the refraction of the atmosphere near the horizon, the bodies of the sun and moon are raised more than 32

minutes above their true places, which is equal, and sometimes more than equal, to the apparent diameters of these bodies.

### *Extraordinary Cases of Refraction in Relation to Terrestrial Objects.*

In consequence of the accidental condensation of certain strata of the atmosphere, some very singular effects have been produced in the apparent elevation of terrestrial objects to a position much beyond that in which they usually appear. The following instance is worthy of notice. It is taken from the Philosophical Transactions of London for 1798, and was communicated by W. Latham, Esq., F.R.S., who observed the phenomenon from Hastings, on the south coast of England: "On July 26, 1797, about five o'clock in the afternoon, as I was sitting in my dining-room in this place, which is situated upon the Parade, close to the seashore, nearly fronting the south, my attention was excited by a number of people running down to the seaside. Upon inquiring the reason, I was informed that the coast of France was plainly to be distinguished by the naked eye. I immediately went down to the shore, and was surprised to find that, even without the assistance of a telescope, I could very plainly see the cliffs on the opposite coast, which, at the nearest part, are between forty and fifty miles distant, and are not to be discerned from that low situation by the aid of the best glasses. They appeared to be only a few miles off, and seemed to extend for some leagues along the coast. I pursued my walk along the shore eastward, close to the water's edge, conversing with the sailors and fishermen upon the subject. They at first would not be persuaded of the reality of the appearance; but they soon became so thoroughly convinced by the cliffs gradually appearing more elevated, and approaching nearer, as it were, that they pointed out and named to me the different places they had been accustomed to visit, such as the Bay, the Old Head, or Man, the Windmill, &c., at Boulogne, St. Vallery, and other places on the coast of Picardy, which they afterward confirmed, when they viewed them through their telescopes. Their observations were, that the places appeared as near as if they were sailing, at a small distance, into the harbours. The day on which this phenomenon was seen was extremely hot; it was high water at Hastings about two o'clock P.M., and not a breath of wind was stirring the whole day." From the summit of an adjacent hill, a most beautiful scene is said to have presented itself. At one glance the spectators could see Dungeness, Dover Cliffs, and the French coast, all along from Calais to St. Vallery, and, as some affirmed, as far to the westward as Dieppe, which could not be much less than eighty or ninety miles. By the telescope the French fishing-boats were plainly seen at anchor, and the different colours of the land on the heights, with the buildings, were perfectly discernible.

This singular phenomenon was doubtless occasioned by an extraordinary refraction, produced by an unusual expansion or condensation of the lower strata of the atmosphere, arising from circumstances connected with the extreme heat of the season. The objects seem to have been apparently raised far above their natural positions; for, from the beach at Hastings, a straight line, drawn across towards the French coast, would have been intercepted by the curve of the waters. They seem, also, to have been magnified by the refraction, and brought, apparently, four or five times nearer the eye, than in the ordinary state of the atmosphere.

The following are likewise instances of unusual refraction: When Captain Colby was ranging over the coast of Caithness, with the telescope of his great Theodolite, on the 21st of June, 1819, at eight o'clock, P.M., from Corryhabbie Hill, near Mortlich, in Banffshire, he observed a brig over the land of Caithness, sailing to the westward in the Pentland Frith, between the Dunnet and Duncansby heads. Having satisfied himself as to the fact, he requested his assistants, Lieutenants Robe and Dawson, to look through the telescope, which they immediately did, and observed the brig likewise. It was very distinctly visible for several minutes, while the party continued to look at it, and to satisfy themselves as to its position. The brig could not have been less than from ninety to one hundred miles distant; and, as the station on Corryhabbie is not above 850 yards above the sea, the phenomenon is interesting. The thermometer was at 44°. The night and day preceding the sight of the brig had been continually rainy and misty, and it was not till seven o'clock of the evening of the 21st that the clouds cleared off the hill.*

Captain Scoresby relates a singular phenomenon of this kind, which occurred while he was traversing the Polar seas. His ship had been separated by the ice from that of his father for a considerable time, and he was looking out for her every day with great anxiety. At length, one evening, to his utter astonishment, he saw her suspended in the air, in an inverted position, traced on the horizon in the clearest colours, and with the most distinct and perfect representation. He sailed in the direction in which he saw this

* Edinburgh Philosophical Journal for October, 1819, p. 411.

visionary phenomenon, and actually found his father's vessel by its indication. He was divided from him by immense masses of icebergs, and at such a distance that it was quite impossible to have seen the ship in her actual situation, or to have seen her at all, if her spectrum had not been thus raised several degrees above the horizon into the sky by this extraordinary refraction. She was reckoned to be seventeen miles beyond the visible horizon, and thirty miles distant.

Mrs. Somerville states that a friend of hers, while standing on the plains of Hindostan, saw the whole upper chain of the Himalaya Mountains start into view, from a sudden change in the density of the air, occasioned by a heavy shower, after a long course of dry and hot weather. In looking at distant objects through a telescope, over the top of a ridge of hills, about two miles distant, I have several times observed that some of the more distant objects which are sometimes hid by the interposition of a ridge of hills, are at other times distinctly visible above them. I have sometimes observed that objects near the middle of the field of view of a telescope, which was in a fixed position, have suddenly appeared to descend to the lower part, or ascend to the upper part of the field, while the telescope remained unaltered. I have likewise seen, with a powerful telescope, the Bell Rock Lighthouse, at the distance of about twenty miles, to appear as if contracted to less than two-thirds of its usual apparent height, while every part of it was quite distinct and well defined, and in the course of an hour, or less, appeared to shoot up to its usual apparent elevation—all which phenomena are evidently produced by the same cause to which we have been adverting.

Such are some of the striking effects produced by the refraction of light. It enables us to see objects in a direction where they are not; it raises, apparently, the bottoms of lakes and rivers; it magnifies objects when their light passes through dense mediums; it makes the sun appear above the horizon when he is actually below it, and thus increases the length of our day; it produces the Aurora and the evening twilight, which forms, in many instances, the most delightful part of a summer day; it prevents us from being involved in total darkness, the moment after the sun has descended beneath the horizon; it modifies the appearances of the celestial bodies, and the directions in which they are beheld; it tinges the sun, moon, and stars, as well as the clouds, with a ruddy hue when near the horizon: it elevates the appearance of terrestrial objects, and, in certain extraordinary cases, brings them nearer to our view, and enables us to behold them when beyond the line of our visible horizon. In combination with the power of reflection, it creates visionary landscapes, and a variety of grotesque and extraordinary appearances, which delight and astonish, and sometimes appal the beholders. In short, as we shall afterwards see more particularly, the refraction of light through glasses of different figures forms the principle on which telescopes and microscopes are constructed, by which both the remote and the minute wonders of creation have been disclosed to view. So that, had there been no bodies capable of refracting the rays of light, we should have remained for ever ignorant of many sublime and august objects in the remote regions of the universe, and of the admirable mechanism and the countless variety of minute objects which lie beyond the range of the unassisted eye in our lower creation, all of which are calculated to direct our views, and to enlarge our conceptions of the Almighty Creator.

In the operation of the law of refraction in these and numerous other instances, we have a specimen of the diversified and beneficent effects which the Almighty can produce by the agency of a single principle in nature. By the influence of the simple law of gravitation the planets are retained in their orbits, the moon directed in her course around the earth, and the whole of the bodies connected with the sun preserved in one harmonious system. By the same law the mountains of our globe rest on a solid basis, the rivers flow through the plains towards the seas, the ocean is confined to its prescribed boundaries, and the inhabitants of the earth are retained to its surface, and prevented from flying upwards through the voids of space. In like manner, the law by which light is refracted produces a variety of beneficial effects essential to the present constitution of our world and the comfort of its inhabitants. When a ray of light enters obliquely into the atmosphere, instead of passing directly through, it bends a little downward, so that the greater portion of the rays which thus enter the atmospheric mass descend by inflection to the earth. We then enjoy the benefits of that light which would otherwise have been totally lost. We perceive the light of day an hour before the solar orb makes its appearance, and a portion of its light is still retained when it has descended nearly eighteen degrees below our horizon. We thus enjoy, throughout the year, seven hundred and thirty hours of light which would have been lost had it not been refracted down upon us from the upper regions of the atmosphere. To the inhabitants of the polar regions this effect is still more interesting and beneficial. Were it not for their twilight, they would be involved, for a

much longer period than they now are, in perpetual darkness; but by the powerful refraction of light which takes place in the frigid zones, the day sooner makes its appearance towards spring, and their long winter nights are, in certain cases, shortened by the period of thirty days. Under the poles, where the darkness of night would continue six months without intermission, if there were no refraction, total darkness does not prevail during the one half of this period. When the sun sets, at the north pole, about the 23d of September, the inhabitants (if any) enjoy a perpetual aurora till he has descended eighteen degrees below the horizon. In his course through the ecliptic the sun is two months before he can reach this point, during which time there is a perpetual twilight. In two months more he arrives again at the same point, namely, eighteen degrees below the horizon, when a new twilight commences, which is continually increasing in brilliancy for other two months, at the end of which the body of this luminary is seen rising in all its glory. So that, in this region, the light of day is enjoyed in a greater or less degree, for ten months without interruption by the effects of atmospheric refraction; and, during the two months when the influence of the solar light is entirely withdrawn, the moon is shining above the horizon for two half months without intermission; and thus it happens that no more than two separate fortnights are passed in absolute darkness; and this darkness is alleviated by the light of the stars and the frequent coruscations of the Aurora Borealis. Hence it appears that there are no portions of our globe that enjoy, throughout the year, so large a portion of the solar light as these northern regions, which is chiefly owing to the refraction of the atmosphere.

The refraction of light by the atmosphere, combined with its power of reflecting it, is likewise the cause of that universal light and splendour which appears on all the objects around us. Were the earth disrobed of its atmosphere, and exposed naked to the solar beams, in this case we might see the sun without having day, strictly so called. His rising would not be preceded by any twilight as it now is. The most intense darkness would cover us till the very moment of his rising; he would then suddenly break out from under the horizon with the same splendour he would exhibit at the highest part of of his course, and would not change his brightness till the very moment of his setting, when, in an instant, all would be black as the darkest night. At noonday we should see the sun like an intensely-brilliant globe shining in a sky as black as ebony, like a clear fire in the night seen in the midst of an extensive field, and his rays would show us the adjacent objects immediately around us: but the rays which fall on the object remote from us would be for ever lost in the expanse of the heavens. Instead of the beautiful azure of the sky, and the colours which distinguish the face of nature by day, we should see nothing but an abyss of darkness, and the stars shining from a vault as dark as chaos. Thus there would be no day, such as we now enjoy, without the atmosphere: since it is by the refraction and reflections connected with this aerial fluid that light is so modified and directed as to produce all that beauty, splendour, and harmony which appear on the concave of the sky, and on the objects which diversify our terrestrial abode.

The effect of refraction, in respect to *terrestrial* objects, is likewise of a beneficial nature. The quantity of this refraction is estimated by Dr. Maskelyne at one-tenth of the distance of the object observed, expressed in degrees of a great circle. Hence, if the distance be 10,000 fathoms, its tenth part 1000 fathoms, is the sixtieth part of a degree, or one minute, which is the refraction in altitude, Le Gendre estimates it at one-fourteenth, De Lambre at one-eleventh, and others at a twelfth of the distance; but it must be supposed to vary at different times and places according to the varying state of the atmosphere. This refraction, as it makes objects appear to be raised higher than they really are, enlarges the extent of our landscapes, and enables us to perceive distant objects which would otherwise have been invisible. It is particularly useful to the navigator at sea. It is one important object of the mariner, when traversing his course, to look out for capes and headlands, rocks, and islands, so as to descry them as soon as they are within the reach of his eye. Now, by means of refraction, the tops of hills and the elevated parts of coasts are apparently raised into the air, so that they may be discovered several leagues further off on the sea than they would be did no such refractive power exist. This circumstance is therefore a considerable benefit to the science of navigation, in enabling the mariner to steer his course aright, and to give him the most early warning of the track he ought to take, or of the dangers to which he may be exposed.

In short, the effects produced by the refraction and reflection of light on the scenery connected with our globe teach us that these principles, in the hand of the Almighty, might be so modified and directed as to produce the most picturesque, the most glorious, and wonderful phenomena, such as mortal eyes have never yet seen, and of which human imagination can form no conception; and in other worlds, more resplendent and magnificent than ours, such scenes may be fully

realized, in combination with the operation of physical principles and agents with which we are at present unacquainted. From what we already know of the effects of the reflection and the refraction of light, it is not beyond the bounds of probability to suppose that, in certain regions of the universe, light may be reflected and refracted through different mediums, in such a manner as to present to the view of their inhabitants the prominent scenes connected with distant systems and worlds, and to an extent as shall infinitely surpass the effects produced by our most powerful telescopes.

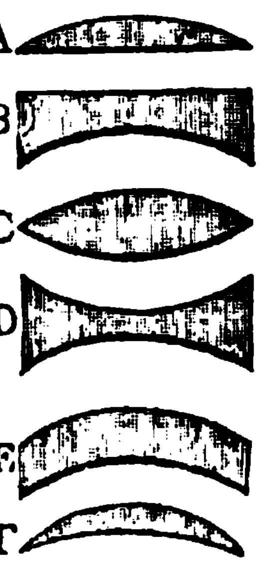
## CHAPTER III.

*On the Refraction of Light through spherical transparent substances, or lenses.*

It is to the refraction of light that we are indebted for the use of lenses or artificial glasses to aid the powers of the vision. It lays the foundation of telescopes, microscopes, camera obscuras, phantasmagorias, and other optical instruments, by which so many beautiful, useful, and wonderful effects have been produced. In order, therefore, to illustrate the principles on which such instruments are constructed, it is necessary to explain the manner in which the rays of light are refracted and modified when passing through spherical mediums of different forms. I do not intend, however, to enter into the minutiæ of this subject, nor into any abstract mathematical demonstrations, but shall simply offer a few explanations of general principles, and several experimental illustrations, which may enable the general reader to understand the construction of the optical instruments to be afterwards described.

A lens is a transparent substance of a different density from the surrounding medium, and terminating in two surfaces, either both spherical, or one spherical and the other plain. It is usually made of *glass*, but may also be formed of any other transparent substance, as ice, crystal, diamonds, pebbles, or fluids of different densities and refractive powers, inclosed between concave glasses. Lenses are ground into various forms, according to the purpose they are intended to serve. They may be generally distinguished as being either *convex* or *concave*. A convex glass is thickest in the middle, and thinner towards the extremities. Of these there are various forms, which are represented in fig. 5. *A* is a *plano-convex* lens, which has one side plane, and the other spherical or convex. *B* is a *plano-concave*, which is plane on the one side and concave on the other. *C* is a *double-convex*, or one which is spherical on both sides. *D*, a *double-concave*, or concave on both sides. *E* is called a *meniscus*, which is convex on one side and concave on the other. *F* is a *concavo-convex*, the convex side of which is of a smaller sphere than the concave. In regard to the *degree* of convexity or concavity in lenses, it is evident that there may be almost an infinite variety. For every convex surface

Fig. 5.



A *Plano-convex.*
B *Plano-concave.*
C *Double Convex.*
D *Double Concave.*
E *Meniscus.*
F *Concavo-convex.*

is to be considered as the segment of a circle, the diameter and the radius of which may vary to almost any extent. Hence lenses have been formed by opticians, varying from one-fiftieth of an inch in radius to two hundred feet. When we speak of the length of the radius of a lens, as, for instance, when we say that a lens is two inches or forty inches radius, we mean that the convex surface of the glass is the part of a circle, the radius of which, or half the diameter, is two inches or forty inches; or, in other words, were the portion of the sphere on which it is ground formed into a globe of corresponding convexity, it would be four inches or eighty inches in diameter.

The *axis* of a lens is a straight line drawn through the centre of its spherical surface; and, as the spherical sides of every lens are arches of circles, the axis of the lens would pass through the centre of that circle of which its sides are segments. *Rays* are those emanations of light which proceed from a luminous body, or from a body that is illuminated. The *Radiant* is that body or object which emits the rays of light, whether it be a self-luminous body, or one that only reflects the rays of light. Rays may proceed from a Radiant in different directions. They may be either parallel, converging, or diverging. *Parallel* rays are those which proceed equally

*distant* from each other through their whole course. Rays proceeding from the sun, the planets, the stars, and distant terrestrial objects are considered as parallel, as in fig. 6. *Converging* rays are such as, proceeding from a body, approach nearer and nearer in their progress, tending to a certain point where they all unite. Thus, the rays proceeding from the object *A B* (fig 7) to the point *F*, are said to converge towards that point. All

Fig. 6.

Fig. 7.

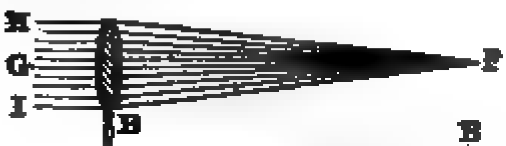
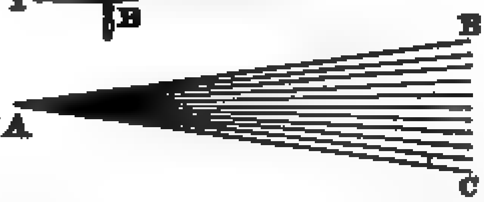



Fig. 8.




convex glasses cause parallel rays which fall upon them to converge, in a greater or less degree; and they render converging rays still more convergent. If *A B*, fig. 7, represent a convex lens, and *H G I* parallel rays falling upon it, they will be refracted, and converge towards the point *F*, which is called the *focus*, or burning point; because, when the sun's rays are thus converged to a point by a large lens, they set on fire combustible substances. In this point the rays meet and intersect each other. *Diverging rays* are those which, proceeding from any point, as *A*, fig 8, continually recede from each other as they pass along in their course towards *B C*. All the rays which proceed from near objects, as a window in a room, or an adjacent house or garden, are more or less divergent. The following figures show the effects of parallel, converging, and diverging rays, in passing through a double convex lens:

Fig. 9 shows the effects of parallel rays, *K A*, *D E*, *L B*, falling on a convex glass, *A B*. The rays which fall near the extremities at *A* and *B* are bent or refracted towards *C F*, the focus, and centre of convexity. It will be observed that they are less refracted as they approach the centre of the lens, and the central ray *D E C*, which is called the *axis* of the lens, and which passes through its centre, suffers no refraction. Fig. 10 exhibits the course of *converging* rays when passing through a similar lens. In this case, the rays converge to a focus *nearer* to the lens than the centre; for a convex lens uniformly increases the convergence of converging rays. The converging rays here representes may be conceived as having been refracted by

Fig. 11. Fig. 9. Fig. 10.

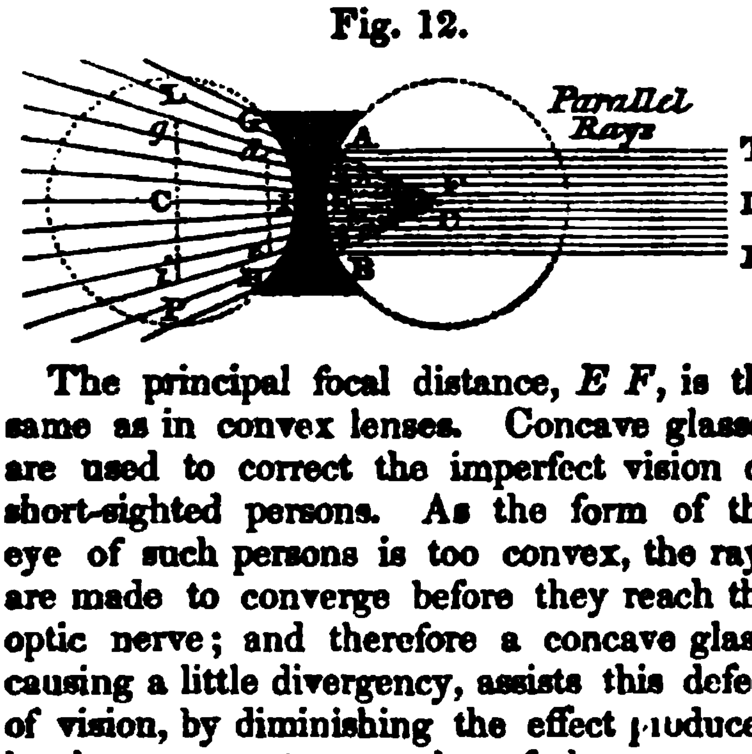
another convex lens of a longer focus, and, passing on towards a point of convergence, were intercepted by the lens *A B*. The point *D* is the place where the rays would have converged to a focus, had they not been thus intercepted. Fig. 11 represents the course of diverging rays when falling on a double convex glass. In this case, the rays *D B*, *D A*, &c., after passing through the lens, converge to a focus at a point considerably further from the lens than its centre, as at *F*. Such rays must be considered as proceeding from near objects, and the fact may be illustrated by the following experiment: Take a common reading glass, and hold it in the rays of the sun, opposite a sheet of writing paper or a white wall, and observe *at what distance* from the glass the rays on the paper converge to a small, distinct white spot. This distance gives the focal length of the lens by parallel rays. If now we hold the glass within a few feet of a window, or a burning candle, and receive its image on the paper, the focal distance of the image from the glass will be found to be longer. If, in the former case, the focal distance was twelve inches, in the latter case it will be thirteen, fifteen, or sixteen inches, according to the distance of the window or the candle from the glass.

If the lens *A B*, fig. 9, on which parallel rays are represented as falling, were a *plano-convex*, as represented at A. fig. 5, the rays would converge to a point *P*, at double the radius, or the whole diameter of the sphere of which it is a segment. If the thickness of a plano-convex be considered, and if it be exposed on its convex side to parallel rays, as

those of the sun, the focus will be at the distance of *twice the radius, wanting two-thirds of the thickness of the lens.* But if the same lens be exposed with its plane side to parallel rays, the focus will then be precisely at the distance of twice the radius from the glass.

The effects of *concave* lenses are directly opposite to those of convex. Parallel rays, striking one of those glasses, instead of converging towards a point, are made to *diverge.* Rays already divergent are rendered more so, and convergent rays are made less convergent. Hence objects seen through concave glasses appear considerably smaller and more distant than they really are. The following diagram, fig. 12, represents the course of parallel rays through a double concave lens, where the parallel rays *T A, D E, I B,* &c., when passing through the concave glass *A B,* diverge into the rays *G L, E C, H P,* &c., as if they proceeded from *F,* a point before the lens, which is the principal focus of the lens:

Fig. 12.




The principal focal distance, *E F,* is the same as in convex lenses. Concave glasses are used to correct the imperfect vision of short-sighted persons. As the form of the eye of such persons is too convex, the rays are made to converge before they reach the optic nerve; and therefore a concave glass, causing a little divergency, assists this defect of vision, by diminishing the effect produced by the too great convexity of the eye, and lengthening its focus. These glasses are seldom used, in modern times, in the construction of optical instruments, except as eye-glasses for small pocket perspectives, and opera-glasses.

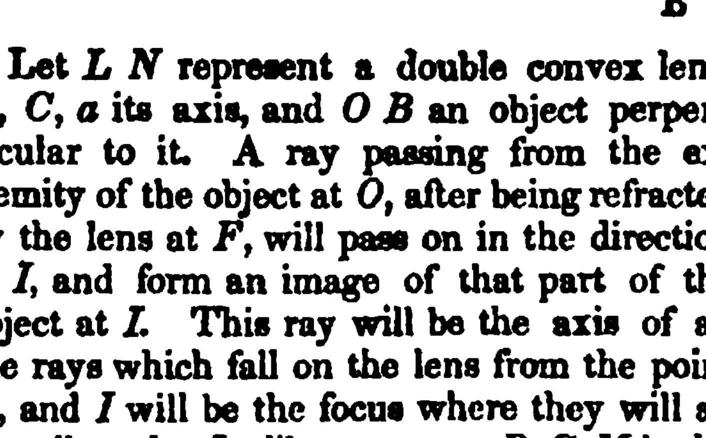
*To find the focal distance of a concave glass.* Take a piece of pasteboard or card paper, and cut a round hole in it, not larger than the diameter of the lens; and on another piece of pasteboard describe a circle whose diameter is just double the diameter of the hole. Then apply the piece with the hole in it to the lens, and hold them in the sunbeams, with the other piece at such a distance behind that the light proceeding from the hole may spread or diverge so as precisely to fill the circle; then the distance of the circle from the lens is equal to its virtual focus, or to its radius, if it be a double concave, and to its diameter, if a plano-concave. Let *d, e* (fig. 12,) represent the diameter of the hole, and *g, i,* the diameter of the circle, then the distance *C, I,* is the virtual focus of the lens.*

The *meniscus,* represented at *E,* fig. 5, is like the crystal of a common watch, and, as the convexity is the same as the concavity, it neither magnifies nor diminishes. Sometimes, however, it is made in the form of a crescent, as at *F,* fig. 5, and is called a *concavo-convex* lens; and, when the convexity is greater than the concavity, or when it is thickest in the middle, it acts nearly in the same way as a double or plano-convex lens of the same focal distance.

### *Of the* IMAGES *formed by Convex Lenses.*

It is a remarkable circumstance, and which would naturally excite admiration, were it not so common and well known, that *when the rays of light from any object are refracted through a convex lens, they paint a distinct and accurate picture of the object before it, in all its colours, shades, and proportions.* Previous to experience, we could have had no conception that light, when passing through such substances, and converging to a point, could have produced so admirable an effect—an effect on which the construction and utility of all our optical instruments depend. The following figure will illustrate this position:

Fig. 13.




Let *L N* represent a double convex lens, *A, C, a* its axis, and *O B* an object perpendicular to it. A ray passing from the extremity of the object at *O,* after being refracted by the lens at *F,* will pass on in the direction *F I,* and form an image of that part of the object at *I.* This ray will be the axis of all the rays which fall on the lens from the point *O,* and *I* will be the focus where they will all be collected. In like manner, *B C M* is the axis of that parcel of rays which proceed from

* This mode of finding the focus of a concave lens may be varied as follows: Let the lens be covered with paper, having two small circular holes; and, on the paper for receiving the light, describe also two small circles, but with their centres at twice the distance from each other of the centres of the circles. Then move the paper to and from, till the middle of the sun's light, coming through the holes, falls exactly on the middle of the circles; that distance of the paper from the lens will be the focal length required.

the extremity of the object *B*, and their focus will be at *M*; and since all the points in the object between *O* and *B* must necessarily have their foci between *I* and *M* a complete picture of the points from which they come will be depicted, and consequently an image of the whole object *O B*.

It is oviouss, from the figure, that the image of the object is formed in the focus of the lens in an *inverted position*. It must necessarily be in this position, as the rays cross at *C*, the centre of the lens; and as it is impossible that the rays from the upper part of the object, *O*, can be carried by refraction to the upper end of the image at *M*. This is a universal principle in relation to convex lenses of every description, and requires to be attended to in the construction and use of all kinds of telescopes and microscopes. It is easily illustrated by experiment. Take a convex lens of eight, twelve, or fifteen inches focal distance, such as a reading glass, or the glass belonging to a pair of spectacles, and holding it, at its focal distance from a white wall, in a line with a burning candle, the flame of the candle will be seen depicted on the wall in an inverted position, or turned upside down. The same experiment may be performed with a window-sash, or any other bright object. But the most beautiful exhibition of the images of objects formed by convex lenses is made by darkening a room, and placing a convex lens of a long focal distance in a hole cut out of the window-shutter; when a beautiful inverted landscape, or picture of all the objects before the window, will be painted on a white paper or screen placed in the focus of the glass. The image thus formed exhibits not only the proportions and colours, but also the motions of all the objects opposite the lens, forming, as it were, a living landscape. This property of lenses lays the foundation of the camera obscura, an instrument to be afterward described.

The following principles in relation to images formed by convex lenses may be stated: 1. That *the image subtends the same angle at the centre of the glass as the object itself does.* Were an eye placed at *C*, the centre of the lens *L N*, fig. 13, it would see the object *O B* and the image *I M* under the same optical angle, or, in other words, they would appear equally large; for, whenever right lines intersect each other, as *O I* and *B M*, the opposite angles are always equal, that is, the angle *M C I* is equal to the angle *O C B*. 2. *The length of the image formed by a convex lens is, to the length of the object, as the distance of the image is to the distance of the object from the lens;* that is, *M I* is to *O B* : : as C A to *C A*. Suppose the distance of the object *C A* from the lens to be forty-eight inches, the length of the object *O B* = sixteen inches, and the distance of the image from the lens six inches, then the length of the image will be found by the following proportion, 48 : 16 : : 6 : 2, that is, the length of the image, in such a case, is two inches. 3. *If the object be at an infinite distance, the image will be formed exactly in the focus.* 4. *If the object be at the same distance from the lens as its focus, the image is removed to an infinite distance on the opposite side;* in other words, the rays will proceed in a *parallel* direction. On this principle, lamps on the streets are sometimes directed to throw a bright light along a footpath where it is wanted, when a large convex glass is placed at its focal distance from the burner; and on the same principle, light is thrown to a great distance from lighthouses, either by a very large convex lens of a short focal distance, or by a concave reflector. 5. *If the object be at double the distance of the focus from the glass, the image will also be at double the distance of the focus from the glass.* Thus, if a lens of six inches focal distance be held at twelve inches' distance from a candle, the image of the candle will be formed at twelve inches from the glass on the other side. 6. *If the object be a little further from the lens than its focal distance, an image will be formed at a distance from the object, which will be greater or smaller in proportion to the distance.* For example, if a lens five inches focus be held at a little more than five inches from a candle, and a wall or screen at five feet six inches distant receive the image, a large and inverted image of the candle will be depicted, which will be magnified in proportion as the distance of the wall from the candle exceeds the distance of the lens from the candle. Suppose the distance of the lens to be five and a half inches, then the distance of the wall where the image is formed, being twelve times greater, the image of the candle will be magnified twelve times. If *M I* (fig. 13) be considered as the object, then *O B* will represent the magnified image on the wall. On this principle, the image of the object is formed by the small object glass of a compound microscope. On the same principle, the large pictures are formed by the Magic Lantern and the Phantasmagoria; and in the same way small objects are represented in a magnified form on a sheet or wall by the Solar microscope. 7. *All convex lenses magnify the objects seen through them, in a greater or less degree.* The shorter the focal distance of the lens, the greater is the magnifying power. A lens four inches focal distance will magnify objects placed in the focus two times in length and breadth; a lens two

inches focus will magnify four times; a lens one inch focus eight times; a lens half an inch focus sixteen times, &c., supposing eight inches to be the least distance at which we see near objects distinctly. In viewing objects with small lenses, the object to be magnified should be placed exactly at the focal distance of the lens, and the eye at about the same distance on the other side of the lens. When we speak of magnifying power, as, for example, that a lens one inch focal distance magnifies objects eight times, it is to be understood of the *lineal* dimensions of the object. But as every object at which we look has breadth as well as length, the *surface* of the object is in reality magnified sixty-four times, or the square of its lineal dimensions; and for the same reason a lens half an inch focal distance magnifies the *surfaces* of objects 256 times.

### *Reflections deduced from the preceding Subject.*

Such are some of the leading principles which require to be recognized in the construction of refracting telescopes, microscopes, and other dioptric instruments whose performance chiefly depends on the *refraction* of light. It is worthy of particular notice, that all the phenomena of optical lenses now described depend upon that peculiar property which the Creator has impressed upon the rays of light, that, *when they are refracted to a focus by a convex transparent substance, they depict an accurate image of the objects whence they proceed.* This, however, common, and however much overlooked by the bulk of mankind, is, indeed, a very wonderful property with which light has been endued. Previous to experience, we could have had no conception that such an effect would be produced; and, in the first instance, we could not possibly have traced it to all its consequences. All the objects in creation might have been illuminated as they now are, for aught we know, without sending forth either direct or reflected rays *with the property of forming exact representations of the objects whence they proceed.* But this we find to be a universal law in regard to light of every description, whether as emanating directly from the sun, or as reflected from the objects he illuminates, or as proceeding from bodies artificially enlightened. It is a law or a property of light not only in our own system, but throughout all the systems of the universe to which mortal eyes have yet penetrated. The rays from the most distant star which astronomers have described are endued with this property, otherwise they could never have been perceived by means of our optical instruments; for it is by the pictures or images formed in these instruments that such distant objects are brought to view. Without this property of light, therefore, we should have had no telescopes, and, consequently, we could not have surveyed, as we can now do, the hills and vales, the deep caverns, the extensive plains, the circular ranges of mountains, and many other novel scenes which diversify the surface of our moon. We should have known nothing of the stupendous spots which appear on the surface of the sun—of the phases of Venus—of the satellites and belts of Jupiter—of the majestic rings of Saturn—of the existence of Uranus and his six moons, or of the planets Vesta, Juno, Ceres, and Pallas, nor could the exact bulks of any of these bodies have been accurately determined. But, above all, we should have been entirely ignorant of the wonderful phenomena of double stars—which demonstrate that suns revolve around suns—of the thousands and millions of stars which crowd the profundities of the Milky Way and other regions of the heavens—of the thousands of nebulæ or starry systems which are dispersed throughout the immensity of the firmament, and many other objects of sublimity and grandeur, which fill the contemplative mind with admiration and awe, and raise its faculties to higher conceptions than it could otherwise have formed of the omnipotence and grandeur of the Almighty Creator.

Without this property of the rays of light, we should, likewise, have wanted the use of the microscope, an instrument which has disclosed a world invisible to common eyes, and has opened to our view the most astonishing exhibitions of Divine mechanism, and of the wisdom and intelligence of the Eternal Mind. We should have been ignorant of those tribes of living beings, invisible to the unassisted eye, which are found in water, vinegar, and many other fluids, many of which are twenty thousand times smaller than the least visible point, and yet display the same admirable skill and contrivance in their construction as are manifested in the formation of the larger animals. We should never have beheld the purple tide of life, and even the globules of the blood rolling with swiftness through veins and arteries smaller than the finest hair; or had the least conception that numberless species of animated beings, so minute that a million of them are less than a grain of sand, could have been rendered visible to human eyes, or that such a number of vessels, fluids, movements, diversified organs of sensation, and such a profusion of the richest ornaments and the gayest colours could have been concentrated in a single point. We should never have conceived that even the atmosphere is replenished with invisible animation

that the waters abound with countless myriads of sensitive existence, that the whole earth is full of life, and that there is scarcely a tree, plant, or flower but affords food and shelter to a species of inhabitants peculiar to itself, which enjoy the pleasures of existence and share in the bounty of the Creator. We could have formed no conception of the beauties and the varieties of mechanism which are displayed in the scenery of that invisible world to which the microscope introduces us—beauties and varieties, in point of ornament and delicate contrivance, which even surpass what is beheld in the visible operations and aspect of nature around us. We find joints, muscles, a heart, stomach, entrails, veins, arteries, a variety of motions, a diversity of forms, and a multiplicity of parts and functions in breathing atoms. We behold in a small fibre of a peacock's feather, not more than one-eighth of an inch in length, a profusion of beauties no less admirable than is presented by the whole feather to the naked eye, a stem sending out multitudes of lateral branches, each of which emits numbers of little sprigs, which consist of a multitude of bright shining globular parts, adorned with a rich variety of colours. In the sections of plants, we see thousands and ten thousands of tubes and pores, and other vessels for the conveyance of air and juices for the sustenance of the plant; in some instances, more than ten hundred thousand of these being compressed within the space of a quarter of an inch in diameter, and presenting to the eye the most beautiful configurations. There is not a weed, nor a moss, nor the most insignificant vegetable, which does not show a multiplicity of vessels disposed in the most curious manner for the circulation of sap for its nourishment, and which is not adorned with innumerable graces for its embellishment. All these and ten thousands of other wonders which lie beyond the limits of natural vision, in this new and unexplored region of the universe, would have been for ever concealed from our view, had not the Creator endued the rays of light with the power of *depicting the images of objects*, when refracted by convex transparent substances.

In this instance, as well as in many others, we behold a specimen of the admirable and diversified effects which the Creator can produce from the agency of a single principle in nature. By means of optical instruments, we are now enabled to take a more minute and expansive view of the amazing operations of nature, both in heaven and on earth, than former generations could have surmised. These views tend to raise our conceptions of the attributes of that Almighty Being who presides over all the arrangements of the material system, and to present them to our contemplation in a new, a more elevated, and expansive point of view. There is, therefore, a connexion which may be traced between the apparently accidental principle of the rays of light forming images of objects and the comprehensive views we are now enabled to take of the character and perfections of the Divinity. Without the existence of the law or principle alluded to, we could not, in the present state, have formed precisely the same conceptions either of the Omnipotence, or of the wisdom and intelligence of the Almighty. Had no microscope ever been invented, the idea never could have entered into the mind of man that worlds of living beings exist beyond the range of natural vision, that organized beings, possessed of animation, exist, whose whole bulk is less than the ten hundred thousandth part of the smallest grain of sand; that, descending from a visible point to thousands of degrees beyond it, an invisible world exists, peopled with tribes of every form and size, the extent of which, and how far it verges towards infinity downward, mortals have never yet explored, and perhaps will never be able to comprehend. This circumstance alone presents before us the perfections of the Divinity in a new aspect, and plainly intimates that it is the will and the intention of the Deity that we should explore his works, and investigate the laws by which the material world is regulated, that we may acquire more expansive views of his character and operations. The inventions of man, in relation to art and science, are not, therefore, to be considered as mere accidental occurrences, but as special arrangements in the Divine government, for the purpose of carrying forward the human mind to more clear and ample views of the scenes of the universe, and of the attributes and the agency of Him "who is wonderful in counsel and excellent in working."

## CHAPTER IV.

### *On the Reflection of Light.*

The *reflection* of the rays of light is that property by which, after approaching the surfaces of bodies, they are thrown back, or repelled. It is in consequence of this property that all

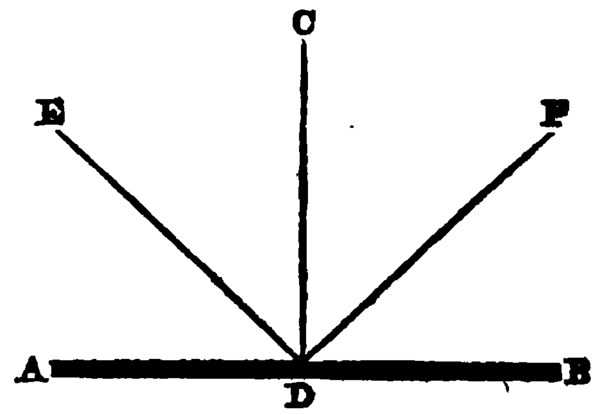
the objects around us, and all the diversified landscapes on our globe are rendered visible. It is by light reflected from their surfaces that we perceive the planetary bodies and their satellites, the belts of Jupiter, the rings of Saturn, the various objects which diversify the surface of the Moon, and all the bodies in the universe which have no light of their own. When the rays of light fall upon rough and uneven surfaces, they are reflected very irregularly, and scattered in all directions, in consequence of which thousands of eyes, at the same time, may perceive the same objects, in all their peculiar colours, aspects and relations. But when they fall upon certain smooth and polished surfaces, they are reflected with regularity, and according to certain laws. Such surfaces, when highly polished, are called *Mirrors* or *Speculums;* and it is to the reflection of light from such surfaces, and the effects it produces, that I am now to direct the attention of the reader.

Mirrors, or specula, may be distinguished into three kinds, *plane*, *concave*, and *convex*, according as they are bounded by plane or spherical surfaces. These are made either of *metal* or of *glass*, and have their surfaces highly polished for the purpose of reflecting the greatest number of rays. Those made of glass are foliated or quicksilvered on one side; and the metallic specula are generally formed of a composition of different metallic substances, which, when accurately polished, is found to reflect the greatest quantity of light. I shall, in the first place, illustrate the phenomena of reflection produced by *plane mirrors*.

When light impinges, or falls, upon a polished flat surface, rather more than the half of it is reflected, or thrown back in a direction similar to that of its approach; that is to say, if it fall *perpendicularly* on the polished surface, it will be perpendicularly reflected; but if it fall *obliquely*, it will be reflected with the same obliquity. Hence, the following fundamental law regarding the reflection of light has been deduced both from experiment and mathematical demonstration, namely, that *the angle of reflection is, in all cases, exactly equal to the angle of incidence.* This is a law which is universal in all cases of reflection, whether it be from plane or spherical surfaces, or whether these surfaces be concave or convex, and which requires to be recognized in the construction of all instruments which depend on the reflection of the rays of light. The following figure (fig. 14) will illustrate the position now stated:

Let *A B* represent a plane mirror, and *C D* a line or ray of light perpendicular to it. Let *F D* represent the *incident* ray from any object, then *D E* will be the reflected ray, thrown back in the direction from *D* to *E*, and it will make, with the perpendicular *C*

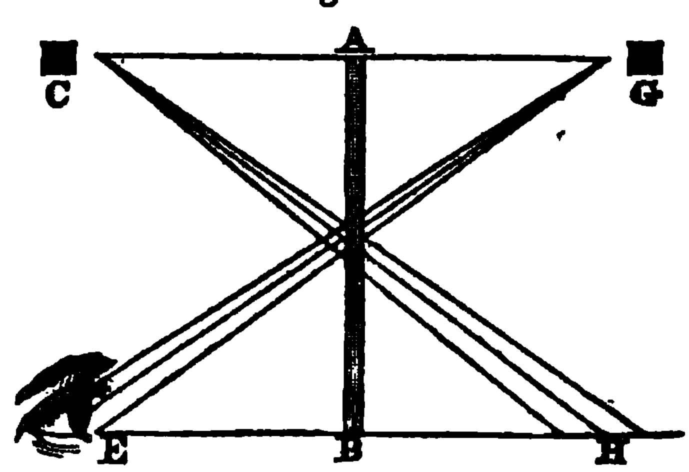
Fig. 14.




*D*, the same angle which the incident ray *F D* did with the same perpendicular; that is, the angle *F D C* will be equal to the angle *E D C*, in all cases of obliquity. The incident ray of light may be considered as rebounding from the mirror, like a tennis ball from a marble pavement, or the wall of a court.

In viewing objects by reflection, we see them in a different direction from that in which they really are, namely, along the line in which the rays come to us last. Thus, if *A B* (fig. 15) represent a plane mirror, the image of an object, *C*, appears to the eye at *E*, behind the mirror, in the direction *E G*, and always in the intersection *G* of the per-

Fig. 15.




pendicular *C G*, and the reflected ray *E G*; and, consequently, at *G* as far behind the mirror as the object *C* is before it. We therefore see the image in the line *E G*, the direction in which the reflected rays proceed. A plane mirror does not alter the figure or size of objects; but the whole image is equal and similar to the whole object, and has a like situation with respect to one side of the plane, that the object has with respect to the other.

Mr. Walker illustrates the manner in which we see our faces in a mirror by the following figure (16) A B represents a mirror, and O C a person looking into it. If we conceive a ray proceeding from the forehead C B, it will be sent to the eye at O, agreeably to the angle of incidence and reflection. But the mind puts C B O into one line, and the forehead is

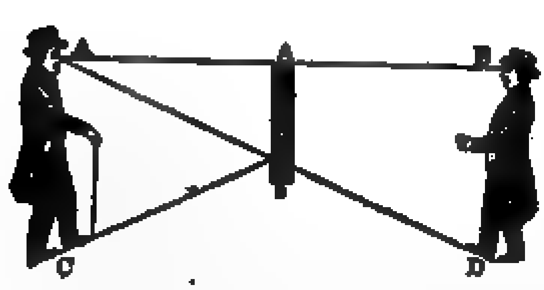
seen at E, as if the lines C E O had turned on a hinge at E. It seems a wonderful faculty of

Fig. 16.

the mind to put the two oblique lines C E and O E into one straight line O E, yet it is seen every time we look at a mirror. For the ray has really travelled from C to E, and from E to O, and it is that journey which determines the distance of the object; and hence we see ourselves as far beyond the mirror as we stand from it. Though a ray is here taken only from one part of the face, it may be easily conceived that rays from every other part of the face must produce a similar effect.

In every plane mirror the image is always equal to the object, at what distance soever it may be placed; and, as the mirror is only at half the distance of the image from the eye, it will completely receive an image of *twice* its own length. Hence, a man six feet high may view himself completely in a looking-glass of three feet in length and half his own breadth; and this will be the case at whatever distance he may stand from the glass. Thus, the man *A C* (fig. 17) will see the whole of

Fig. 17.



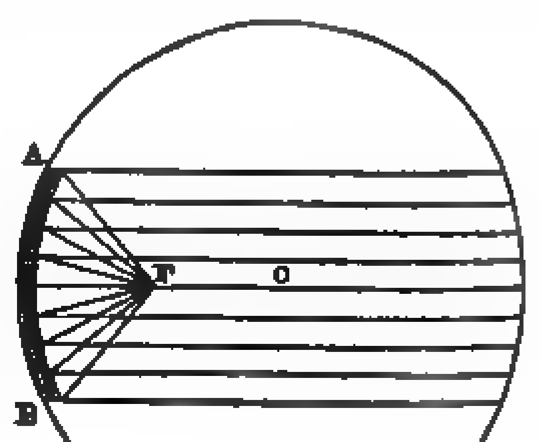

his own image in the glass A B, which is but one half as large as himself. The rays from the head pass to the mirror in the line *A* A, perpendicular to the mirror, and are returned to the eye in the same line; consequently, having travelled twice the length *A* A, the man must see his head at *B*. From his feet, *C*, rays will be sent to the bottom of the mirror, at B; these will be reflected at an equal angle to the eye in the direction B A, as if they had proceeded in the direction *D* B *A*, so that the man will see his foot at *D*, and, consequently, his whole figure at *B D*.

A person, when looking into a mirror, will always see his own image as far beyond the mirror as he is before it; and as he moves to or from it, the image will, at the same time, move towards or from him on the other side, but apparently with a double velocity, because the two motions are equal and contrary. In like manner, if, while the spectator is at rest, an object be in motion, its image behind the mirror will be seen to move at the same time. And if the spectator moves, the images of objects that are at rest will appear to approach or recede from him, after the same manner as when he moves towards real objects; plane mirrors reflecting not only the object, but the distance also, and that exactly in its natural dimensions. The following principle is sufficient for explaining most of the phenomena seen in a plane mirror, namely: *That the image of an object seen in a plane mirror is always in a perpendicular to the mirror joining the object and the image, and that the image is as much on one side the mirror as the object is on the other.*

### *Reflection by Convex and Concave Mirrors.*

Both convex and concave mirrors are formed of portions of a sphere. A convex speculum is ground and polished in a *concave* dish or tool which is a portion of a sphere, and a concave speculum is ground upon a convex tool. The inner surface of a sphere brings parallel rays to a focus at *one-fourth* of its diameter, as represented in the following figure, where *C* is the centre of the sphere

Fig. 18.



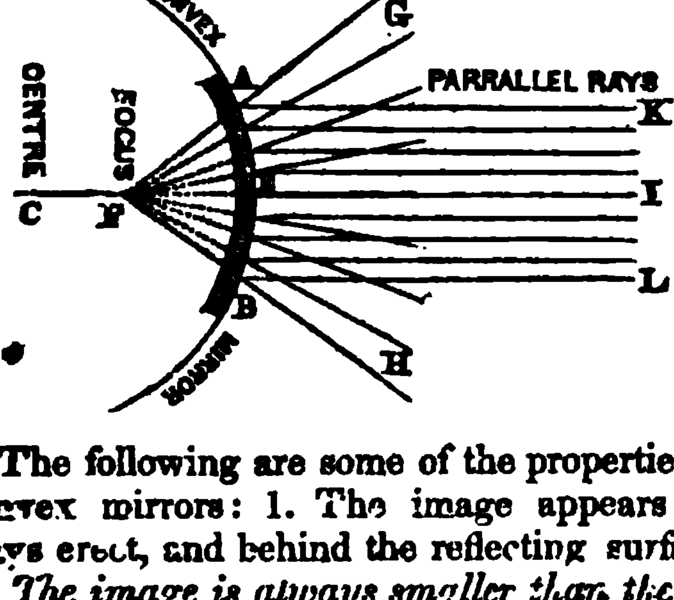

on which the concave speculum *A B* is formed, and *F* the focus where parallel rays from a distant object would be united after reflec-

tion, that is, at one-half the radius, or one-fourth of the diameter from the surface of the speculum. Were a speculum of this kind presented to the sun, $F$ would be the point where the reflected rays would be converged to a focus, and set fire to combustible substances if the speculum be of a large diameter, and of a short focal distance. Were a candle placed in that focus, its light would be reflected parallel, as represented in the figure. These are properties of concave specula which require to be particularly attended to in the construction of reflecting telescopes. It follows, from what has been now stated, that, if we intend to form a speculum of a certain focal distance, for example, two feet, it is necessary that *it should be ground upon a tool whose radius is double that distance*, or four feet.

*Properties of Convex Mirrors.*

From a convex surface, parallel rays, when reflected, are made to diverge: convergent rays are reflected less convergent; and divergent rays are rendered more divergent. It is the nature of all convex mirrors and surfaces to scatter or *disperse* the rays of light, and in every instance to impede their convergence. The following figure shows the course of parallel rays as reflected from a convex mirror. $A\ E\ B$ is the convex surface of the mirror, and $K\ A$, $I\ E$, $L\ B$ parallel rays falling upon it. These rays, when they strike the mirror, are made to diverge in the direction $A\ G$, $B\ H$, &c., and both the parallel and divergent rays are here represented as they appear in a dark chamber when a convex mirror is presented to the solar rays. The dotted lines denote only the course or tendency of the reflected rays towards the *virtual* focus $F$, were they not intercepted by the mirror. This virtual focus is just equal to half the radius $C\ E$.

Fig. 19.




The following are some of the properties of convex mirrors: 1. The image appears always erect, and behind the reflecting surface. 2. *The image is always smaller than the object*, and the diminution is greater in proportion as the object is further from the mirror; but if the object touch the mirror, the image at the point of contact is of the same size as the object. 3. The image does not appear so far behind the reflecting surface as in a plane mirror. 4. The image of a straight object, placed either parallel or oblique to the mirror, is seen *curved* in the mirror, because the different points of the object are not all at an equal distance from the surface of the mirror. 5. Concave mirrors have a *real* focus where an image is actually formed; but convex specula have only a *virtual* focus, and this focus is behind the mirror, no image of any object being formed before it.

The following are some of the purposes to which convex mirrors are applied; They are frequently employed by painters for reducing the proportions of the objects they wish to represent, as the images of objects diminish in proportion to the smallness of the radius of convexity, and to the distances of objects from the surface of the mirror. They form a fashionable part of modern furniture, as they exhibit a large company assembled in a room, with all the furniture it contains, in a very small compass, so that a large hall, with all its objects, and even an extensive landscape, being reduced in size, may be seen from one point of view. They are likewise used as the small specula of those reflecting telescopes which are fitted up on the *Cassegrainian* plan, and in the construction of Smith's Reflecting Microscope. But, on the whole, they are very little used in the construction of optical instruments.

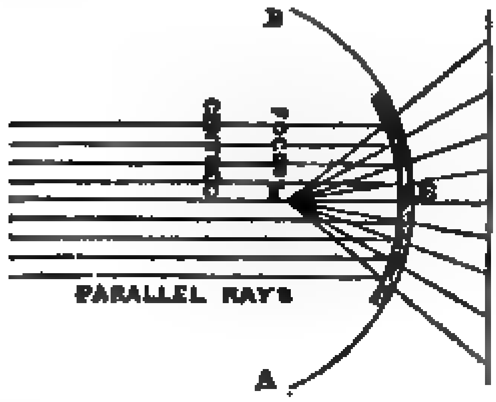
*Properties of Concave Speculums.*

Concave specula have properties very different from those which are convex; they are of more importance in the construction of reflecting telescopes and other optical instruments, and therefore require more minute description and illustration. Concave mirrors cause parallel rays to converge; they increase the convergence of rays that are already converging; they diminish the divergence of diverging rays, and in some cases render them parallel, and even convergent; which effects are all in proportion to the concavity of the mirror. The following figures show the course of diverging and parallel rays as reflected from concave mirrors.

Fig. 20 represents the course of *parallel* rays, and $A\ B$ the concave mirror on which they fall. In this case, they are reflected so as to unite at $F$, which point is distant from its surface *one-fourth* of the diameter of the sphere of the mirror. This point is called the focus of parallel rays, or *the true focus of the mirror*; and, since the sunbeams are parallel among themselves, if they are re-

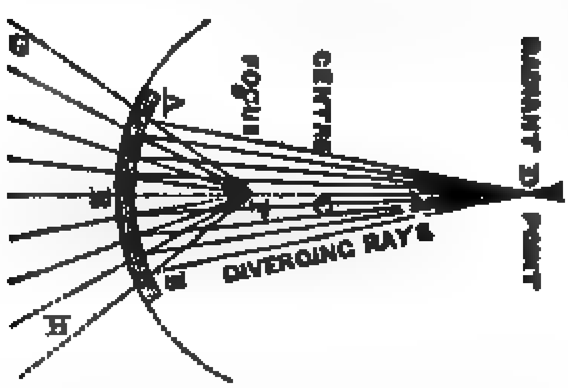
ceived on a concave mirror, they will be reflected to that point, and there burn in pro-

Fig. 20.




portion to the quantity of rays collected by the mirror. Fig 21 shows the direction of *diverging* rays, or those which proceed from a near object. These rays proceeding from an object further from the mirror than the

Fig. 21.




true focal point, as from $D$ to $A$ and to $B$, are reflected converging, and meet at a point $F$, *further from the mirror* than the focal point of parallel rays. If the distance of the radiant, or object $D$, be equal to the radius $C\ E$, then will the focal distance be likewise equal to the radius; that is, if an object be placed in the centre of a concave speculum, the image will be reflected upon the object, or they will seem to meet and embrace each other in the centre. If the distance of the radiant be equal to half the radius, its image will be reflected to an infinite distance, for the rays will then be parallel. If, therefore, a luminous body be placed at half the radius from a concave speculum, it will enlighten places directly before it at great distances. Hence their use when placed behind a candle in a common lantern; hence their utility in throwing light upon objects in the Magic Lantern and Phantasmagoria; and hence the vast importance of very large mirrors of this description, as now used in most of our light-houses, for throwing a brilliant light to great distances at sea, to guide the mariner when directing his course under the cloud of night.

When *converging* rays fall upon a concave mirror, they are reflected more converging and unite at a point between the focus of parallel rays and the mirror; that is, nearer the mirror than one-half the radius; and their precise degree of convergency will be greater than that wherein they converged before reflection.

*Of the Images formed by Concave Mirrors.*

If rays proceeding from a distant object fall upon a concave speculum, they will paint an image or representation of the object on its focus *before* the mirror. This image will be inverted, because the rays cross at the points where the image is formed. We have already seen that a convex glass forms an image of an object *behind* it; the rays of light from objects *pass through* the glass, and the picture is formed on the side furthest from the object. But in concave mirrors the images of distant objects—and of all objects that are further from its surface than its principal focus—are formed *before* the mirror, or on the same side as the object. In almost every other respect, however, the effect of a concave mirror is the same as that of a convex lens, in regard to the formation of images, and the course pursued by the rays of light, except that the effect is produced in the one case by refraction, and in the other by reflection. The following figure represents the manner

Fig. 22.

in which images are formed by concave mirrors; $G\ F$ represents the reflecting surface of the mirror; $O\ A\ B$, the object; and $I\ a\ M$ the image formed by the mirror. The rays proceeding from O will be carried to the mirror in the direction $O\ G$, and, according to the law that the angle of incidence is equal to the angle of reflection, will be reflected to $I$ in the direction $G\ I$. In like manner, the rays from $B$ will be reflected from $F$ to $M$, the rays from $A$ will be reflected to $a$, and so of all the intermediate rays, so that an inverted image of the object $O\ B$ will be formed at $I\ M$. If the rays proceeded from objects at a

very great distance, the image would be formed in the real focus of the mirror, or at one-fourth the diameter of the sphere from its surface; but nearer objects, which send forth diverging rays, will have their images formed a little further from the surface of the mirror.

If we suppose a real object placed at *I M*, then *O B* will represent its magnified image, which will be larger than the object in proportion to its distance from the mirror. This may be experimentally illustrated by a concave mirror and a candle. Suppose a concave mirror whose focal distance is five inches, and that a candle is placed before it at a little beyond its focus (as at *I M*,) suppose at five and a half inches, and that a wall or white screen receives the image, at the distance of five feet six inches from the mirror, an image of the candle will be formed on the wall which will be twelve times longer and broader than the candle itself. In this way concave mirrors may be made to magnify the images of objects to an indefinite extent. This experiment is an exact counterpart of what is effected in similar circumstances by a convex lens, as described p. 34; the mirror performing the same thing by reflection as the lens did by refraction.

From what has been stated in relation to concave mirrors, it will be easily understood how they make such powerful burning-glasses. Suppose the focal distance of a concave mirror to be twelve inches, and its diameter or breadth twelve inches. When the sun's rays fall on such a mirror, they form an image of the sun at the focal point, whose diameter is found to be about one-tenth of an inch. All the rays which fall upon the mirror are converged into this small point, and, consequently, their intensity is in proportion as the square of the surface of the mirror is to the square of the image. The squares of these diameters are as 14,400 to 1, and, consequently, the density of the sun's rays, in the focus, is to their density on the surface of the mirror as 14,400 to 1. That is, the heat of the solar rays in the focus of such a mirror will be fourteen thousand four hundred times greater than before: a heat which is capable of producing very powerful effects in melting and setting fire to substances of almost every description.

Were we desirous of forming an image by a concave speculum which shall be exactly equal to the object, the object must be placed exactly in the centre; and, by an experiment of this kind, the centre of the concavity of a mirror may be found.

In the cases now stated, the images of objects are all formed in the front of the mirror, or between it and the object. But there is a case in which the image is formed behind the mirror. This happens when the object is placed between the mirror and the focus of parallel rays, and then the image is larger than the object. In fig. 23, *G F* is a concave mirror, whose focus of parallel rays is at *E*. If an object *O B* be placed a little within this

Fig. 23.

focus, as at *A*, a large image *I M* will be seen *behind* the mirror, somewhat curved and erect, which will be seen by an eye looking directly into the front of the mirror. Here the image appears at a greater distance behind the mirror than the object is before it, and the object appears magnified in proportion to its distance from the focus and the mirror. If the mirror be one inch focal distance, and the object be placed eight-tenths of an inch from its surface, the image would be five times as large as the object in length and breadth, and, consequently, twenty-five times larger in surface. In this way small objects may be magnified by reflection, as such objects are magnified by refraction, in the case of deep convex lenses. When such mirrors are large, for example six inches diameter, and eight or ten inches focal distance, they exhibit the human face as of an enormous bulk. This is illustrated by the following figure: Let C E, fig. 24, represent the surface of a concave mirror, and *A* a human face looking into it, the face will appear magnified as represented by the image behind the mirror, D G. Suppose a ray, A C, proceeding from the forehead, and another, M N, from the chin; these rays are reflected

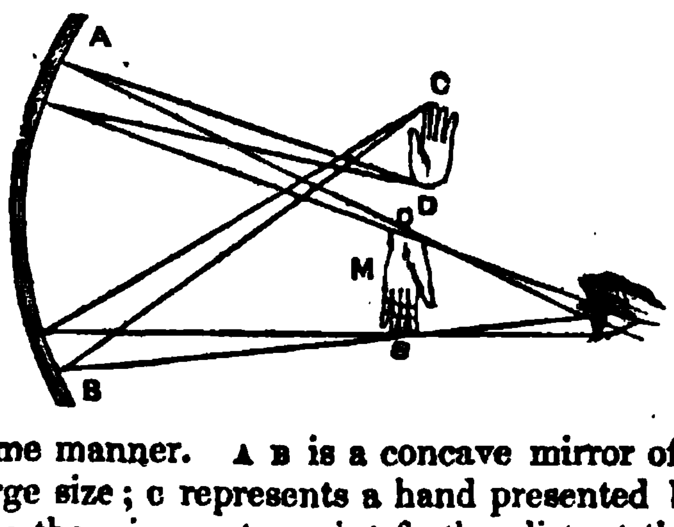
Fig. 24.

to the person's eye at o, which, consequently, sees the image of the lines of reflection o D, o Q, and in the angle D o Q, and, consequently, magnified much beyond the natural size, and at a small distance behind the mirror.

If we suppose the side T U to represent a *convex* mirror, and the figure D Q a head of an ordinary size, then the figure *A* will represent the diminished appearance which a person's face exhibits when viewed in such a mirror. It will not only appear reduced, but somewhat distorted; because, from the form of the mirror, one part of the object is nearer to it than another, and, consequently, will be reflected under a different angle.

The effect we have now mentioned as produced by *concave* mirrors will only take place when the eye is nearer the mirror than its principal focus. If the spectator retire beyond this focus—suppose to the distance of five or six feet—he will not see the image *behind* the mirror, but he will see his image in a diminished form, hanging upside down, and suspended in the air, in a line between his eye and the mirror. In this case, his image is formed *before* the mirror, as represented at *I M*, fig. 22. In this situation, if you hold out your hand towards the mirror, the hand of the image will come out towards your hand, and, when at the centre of concavity, it will be of an equal size with it, and you may shake hands with this aerial image. If you move your hand further, you will find the hand of the image pass by your hand, and come between it and your body. If you move your hand towards either side, the hand of the image will move towards the other side; the image moving always in a contrary direction to the object. All this while the bystanders, if any, see nothing of the image, because none of the reflected rays that form it can enter their eyes. The following figure represents a phenomenon produced in the

Fig. 25.




same manner. A B is a concave mirror of a large size; C represents a hand presented before the mirror, at a point further distant than its focus. In this case an inverted image of the hand is formed, which is seen hanging in the air at M. The rays C and D go diverging from the two opposite points of the object, and, by the action of the mirror, they are again made to converge to points at o and s, where they cross, form an image, and again proceed divergent to the eye.*

In consequence of the properties of concave mirrors now described, many curious experiments and optical deceptions have been exhibited. The appearance of images in the air, suspended between the mirror and the object, have sometimes been displayed with such dexterity, and an air of mystery, as to have struck with astonishment those who were ignorant of the cause. In this way birds, flying angels, spectres, and other objects have been exhibited; and when the hand attempts to lay hold on them, it finds them to be nothing, and they seem to vanish into air. An apple or a beautiful flower is presented, and when a spectator attempts to touch it, it instantly vanishes, and a death's head immediately appears, and seems to snap at his fingers. A person with a drawn sword appears before him, in an attitude as if about to run him through, or one terrific phantom starts up after another, or sometimes the resemblances of deceased persons are made to appear, as if, by the art of conjuration, they had been forced to return from the world of spirits. In all such exhibitions a very large concave mirror is requisite, a brilliant light must be thrown upon the objects, and every arrangement is made, by means of partitions, &c., to prevent either the light, the mirror, or the object from being seen by the spectators. The following representation (fig. 26) shows one of the methods by which this is effected: A is a large concave mirror, either of metal or of glass, placed on the back part of a dark box; D is the performer, concealed from the spectators by the cross partition C; E is a strong light, which is likewise concealed by the partition I, which is thrown upon the actor D or upon any thing he may hold in his hand. If he hold a book, as represented in the figure, the light reflected from it will pass between the partitions C and I to the mirror, and will be reflected from thence to Z, where the image of the book will appear so distinct and tangible, that a spectator looking through the opening at X will imagine that it is in his power to

* Small glass mirrors for performing some of the experiments, and illustrating some of the principles above alluded to, may be made of the flattest kind of common watch glasses, by foliating or covering with tin leaf and quicksilver the convex surfaces of such glasses. Their focal distances will generally be from one to two inches. Such mirrors afford a very large and beautiful view of the eye, when held within their focal distance of that organ. Such mirrors will also serve the purpose of reflecting light on the objects viewed by microscopes. Larger mirrors, of from four to eight inches diameter, may be had of the optician at different prices, varying from five to ten or fifteen shillings.

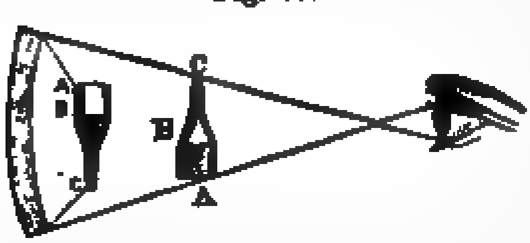
take hold of it. In like manner, the person situated at D may exhibit his own head or

Fig. 26.

body, a portrait, a painting, a spectre, a landscape, or any object or device which he can strongly illuminate.

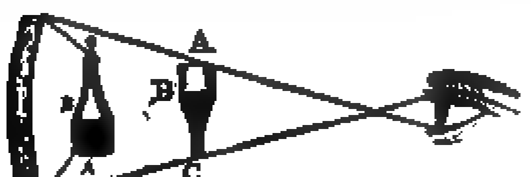
There is another experiment, made with a concave mirror, which has somewhat puzzled philosophers to account for the phenomena. Take a glass bottle, *A C* (fig. 27,) and fill it with water to the point *B*; leave the upper

Fig. 27.



part, *B C*, empty, and cork it in the common manner. Place this bottle opposite a concave mirror, and beyond its focus, that it may appear reversed, and before the mirror place yourself still further distant from the bottle, and it will appear in the situation A B C. Now it is remarkable, in this apparent bottle, that the *water*, which, according to the laws of catoptrics, should appear at A B, appears, on the contrary, at B C, and, consequently, the part A B appears empty. If the bottle be inverted and placed before the mirror, its image will appear in its natural erect position, and the water, which is in reality at *B C* (fig. 28,) is seen at A B. If, while the bottle

Fig. 28.



is inverted, it be uncorked, and the water run gently out, it will appear that, while the part, *B C* is *emptying*, that of A B in the image is filling, and, what is remarkable, as soon as the bottle is empty the illusion ceases, the image also appearing entirely empty. The remarkable circumstances in this experiment are, first, not only to see the object where it is not, but also where its *image* is not; and, secondly, that of two objects which are really in the same place, as the surface of the bottle and the water it contains, the one is seen at one place, and the other at another; and to see the bottle in the place of its image, and the water where neither it nor its image is.

The following experiments are stated by Mr. Ferguson, in his "Lectures on Select Subjects," &c: "If a fire be made in a large room, and a smooth mahogany table be placed at a good distance near the wall, before a large concave mirror, so placed that the light of the fire may be reflected from the mirror to its focus upon the table; if a person stand by the table, he will see nothing upon it but a longish beam of light: but if he stand at a distance towards the fire, not directly between the fire and mirror, he will see an image of the fire upon the table, large and erect. And if another person, who knows nothing of the matter beforehand, should chance to come into the room, and should look from the fire towards the table, he would be startled at the appearance, for the table would seem to be on fire, and by being near the wainscot, to endanger the whole house. In this experiment there should be no light in the room but what proceeds from the fire, and the mirror ought to be at least fifteen inches in diameter. If the fire be darkened by a screen, and a large candle be placed at the back of the screen, a person standing by the candle will see the appearance of a very fine large star, or, rather, planet, upon the table, as bright as Venus or Jupiter. And if a small wax taper—whose flame is much less than the flame of the candle—be placed near the candle, a satellite to the planet will appear on the table; and if the taper be moved round the candle, the satellite will go round the planet."

Many other illustrations of the effects of concave specula might have been given, but I shall conclude this department by briefly stating some of the *general properties of speculums*.

1. There is a great resemblance between the properties of *convex* lenses and *concave* mirrors. They both form an inverted focal image of any remote object, by the convergence of the pencil of rays. In those instruments whose performances are the effects of reflection, as reflecting telescopes, the concave mirror is substituted in the place of the con-

vex lens. The whole effect of these instruments, in bringing to view remote objects in heaven and on earth, entirely depends on the property of a concave mirror in forming *images* of objects in its focus. 2. The image of an object placed beyond the centre is less than the object; if the object be placed between the principal focus and the centre, the image is greater than the object. In both cases the image is inverted. 3. When the object is placed between the focus and the mirror, the image situated *behind* the mirror is greater than the object, and it has the same direction; in proportion as the object approaches the focus, the image becomes larger and more distant. These and similar results are proved by placing a lighted candle at different distances from a concave mirror. 4. An eye cannot see an image in the air except it be placed in the diverging rays; but if the image be received on a piece of white paper, it may be seen in any position of the eye, as the rays are then reflected in every direction. 5. If a picture, drawn according to the rules of perspective, be placed before a large concave speculum, a little nearer than its principal focus, the image of the picture will appear extremely natural, and very nearly like the real objects whence it was taken. Not only are the objects considerably magnified, so as to approach to their natural size, but they have also different apparent distances, as in nature, so that the view of the inside of a church appears very like what it is in reality, and representations of landscapes appear very nearly as they do from the spot whence they were taken. In this respect a large concave speculum may be made to serve nearly the same purpose as the Optical Diagonal Machine in viewing perspective prints. 6. The concave speculum is that alone which is used as the great mirror which forms the first image in reflecting telescopes; and it is likewise the only kind of speculum used as the small mirror, in that construction of the instrument called the *Gregorian Reflector.*

### *Quantity of Light reflected by polished Surfaces.*

As this is a circumstance connected with the construction of reflecting telescopes, it may not be improper, in this place, to state some of the results of the accurate experiments of M. Bonguer on this subject. This philosopher ascertained that of the light reflected from mercury, or quicksilver, more than *one-fourth* is lost, though it is probable that no substances reflect more light than this. The rays were received at an angle of eleven and a half degrees of incidence, measured from the surface of the reflecting body, and not from the perpendicular. The reflection from *water* was found to be almost as great as that of quicksilver; so that in very small angles it reflects nearly three-fourths of the direct light. This is the reason why so strong a reflection appears on the water, when one walks, in still weather, on the brink of a lake opposite to the sun. The direct light of the sun diminishes gradually as it approaches the horizon, while the reflected light at the same time grows stronger; so that there is a certain elevation of the sun in which the united force of the direct and reflected light will be the greatest possible, and this is when he is twelve or thirteen degrees in altitude. On the other hand, light reflected from water at *great angles* of incidence is extremely small. When the light was perpendicular, it reflected no more than the thirty-seventh part which mercury does in the same circumstances, and only the fifty-fifth part of what fell upon it in this case.

Using a smooth piece of glass, one line in thickness, he found that, when it was placed at an angle of fifteen degrees with the incident rays, it reflected 628 parts of 1000 which fell upon it; at the same time, a metallic mirror, which he tried in the same circumstances, reflecting only 561 of them. At a less angle of incidence much more light was reflected; so that at an angle of three degrees the glass reflected 700 parts, and the metal something less, as in the former case. The most striking observations made by this experimenter relate to the very great difference in the quantity of light reflected at different angles of incidence. He found that for 1000 incident rays, the reflected rays, at different angles of incidence, were as follows:

| Angles of incidence. | Rays reflected by water. | Rays reflected by glass. |
|---|---|---|
| 5° | 501 | 549 |
| 10 | 333 | 412 |
| 15 | 211 | 299 |
| 30 | 65 | 112 |
| 50 | 22 | 34 |
| 70 | 18 | 25 |
| 90 | 18 | 25 |

With regard to such mirrors as the specula of reflecting telescopes, it will be found, in general, that they reflect little more than the *one-half* of the rays which fall upon them.

### *Uncommon appearances in Nature produced by the combined Influences of Reflection and Refraction.*

The reflection and refraction of the rays of light frequently produce phenomena which astonish the beholders, and which have been regarded by the ignorant and the superstitious as the effects of supernatural agency. Of these phenomena I shall state a few examples.

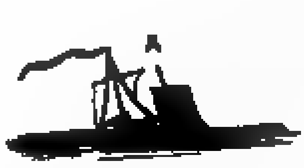
One of the most striking appearances of this kind is what has been termed the *Fata Morgana*, or optical appearances of figures in the sea and the air, as seen in the Faro of Messina. The following account is translated from a work of Minasi, who witnessed the phenomenon, and wrote a dissertation on the subject: "When the rising sun shines from that point whence its incident ray forms an angle of about forty-five degrees to the sea of Riggio, and the bright surface of the water in the bay is not disturbed either by the wind or the current, the spectator being placed on an eminence of the city, with his back to the sun and his face to the sea; on a sudden there appear on the water, as in a catoptric theatre, various multiplied objects, that is to say, numberless series of pilasters, arches, castles well delineated, regular columns, lofty towers, superb palaces, with balconies and windows, extended alleys of trees, delightful plains with herds and flocks, armies of men on foot and horseback, and many other strange images, in their natural colours and proper actions, passing rapidly in succession along the surface of the sea, during the whole of the short period of time, while the above mentioned causes remain. But if, in addition to the circumstances now described, the atmosphere be highly impregnated with vapour and dense exhalations, not previously dispersed by the winds or the sun, it then happens that, in this vapour, as in a curtain extended along the channel, at the height of about thirty palms, and nearly down to the sea, the observer will behold the scene of the same objects, not only reflected from the surface of the sea, but likewise in the air, though not so distant or well defined as the former objects from the sea. Lastly, if the air be slightly hazy or opaque, and, at the same time, dewy, and adapted to form the iris, the then above-mentioned objects will appear only at the surface of the sea, as in the first case, but all vividly coloured or fringed with red, green, blue, and other prismatic colours."*

It is somewhat difficult to account for all the appearances here described, but, in all probability, they are produced by a calm sea, and one or more strata of superincumbent air, differing in refractive, and, consequently, in reflective power. At any rate, reflection and refraction are some of the essential causes which operate in the production of the phenomena.

The *Mirage*, seen in the deserts of Africa, is a phenomenon, in all probability, produced by a similar cause. M. Monge, who accompanied the French army to Egypt, relates that, when in the desert between Alexandria and Cairo, the mirage of the blue sky was inverted, and so mingled with the sand below as to give to the desolate and arid wilderness an appearance of the most rich and beautiful country. They saw, in all directions, green islands, surrounded with extensive lakes of pure, transparent water. Nothing could be conceived more lovely and picturesque than the landscape. In the tranquil surface of the lakes, the trees and houses with which the islands were covered were strongly reflected with vivid and varied hues, and the party hastened forward to enjoy the cool refreshments of shade and stream which these populous villages proffered to them. When they arrived, the lake on whose bosom they floated, the trees among whose foliage they were embowered, and the people who stood on the shore inviting their approach, had all vanished, and nothing remained but a uniform and irksome desert of sand and sky, with a few naked huts and ragged Arabs. Had they not been undeceived by their nearer approach, there was not a man in the French army who would not have sworn that the visionary trees and lakes had a real existence in the midst of the desert.

Dr. Clark observed precisely the same appearance at Rosetta. The city seemed surrounded with a beautiful sheet of water; and so certain was his Greek interpreter—who was unacquainted with the country—of this fact, that he was quite indignant at an Arab who attempted to explain to him that it was a mere optical delusion. At length they reached Rosetta in about two hours, without meeting with any water; and, on looking back on the sand they had just crossed, it seemed to them as if they had waded through a vast blue lake.

Fig. 29.



On the 1st of August, 1798, Dr. Vince observed at Ramsgate a ship which appeared as at A (fig. 29,) the topmast being the only part of it that was seen above the horizon. An inverted image of it was seen at B, immediately above the real ship A, and an erect image at C, both of them being complete and well defined. The sea was distinctly seen between them, as at V W.

* Nicholson's Journal of Natural Philosophy, &c., 4to series, p. 225.

As the ship rose to the horizon, the image C gradually disappeared, and, while this was going on, the image B descended, but the mainmast of B did not meet the mainmast of A. The two images, B C, were perfectly visible when the whole ship was actually below the horizon. Dr. Vince then directed his telescope to another ship whose hull was just in the horizon, and he observed a complete inverted image of it, the mainmast of which just touched the mainmast of the ship itself. He saw at the same time several other ships whose images appeared in nearly a similar manner, in one of which the two images were visible when the whole ship was beneath the horizon. These phenomena must have been produced by the same cause which operated in the case formerly mentioned, in relation to Captain Scoresby, when he saw the figure of his father's ship inverted in the distant horizon. Such cases, are perhaps, not uncommon, especially in calm and sultry weather, but they are seldom observed, except when a person's attention is accidentally directed to the phenomenon, and, unless he use a telescope, it will not be so distinctly perceived.

The following phenomenon, of a description nearly related to the above, has been supposed to be chiefly owing to *reflection:* On the 18th of November, 1804, Dr. Buchan, when watching the rising sun, about a mile to the east of Brighton, just as the solar disk emerged from the surface of the water, saw the face of the cliff on which he was standing, a windmill, his own figure, and the figure of his friend, distinctly represented, precisely opposite, at some distance from the ocean. This appearance lasted about ten minutes, till the sun had risen nearly his own diameter above the sea. The whole then seemed to be elevated into the air, and successively disappeared. The surface of the sun was covered with a dense fog of many yards in height, which gradually receded from the rays of the sun as he ascended from the horizon.

The following appearance, most probably, arose chiefly from the *refraction* of the atmosphere; It was beheld at Ramsgate by Dr. Vince, of Cambridge, and another gentleman. It is well known that the four turrets of Dover Castle are seen at Ramsgate, over a hill which intervenes between a full prospect of the whole. On the 2d of August, 1806, not only were the four turrets visible, but the castle itself appeared as though situated on that side of the hill nearest Ramsgate, and so striking was the appearance that for a long time the doctor thought it an illusion; but at last, by accurate observation, was convinced that it was an actual image of the castle. He, with another individual, observed it attentively for twenty minutes, but were prevented by rain from making further observations. Between the observers and the land from which the hill rises there were about six miles of sea, and from thence to the top of the hill there was about the same distance; their own height above the surface of the water was about seventy feet. The cause of this phenomenon was, undoubtedly, *unequal refraction*. The air being more dense near the ground and above the sea than at greater heights, reached the eye of the observer, not in straight, but in curvilinear lines. If the rays from the castle had in their path struck an eye at a much greater distance than Ramsgate, the probability is that the image of the castle would have been inverted in the air; but, in the present case, the rays from the turret and the base of the castle had not crossed each other.

To similar causes as those now alluded to are to be attributed such phenomena as the following:

*The Spectre of the Brocken.* This is wonderful, and, at first sight, a terrific phenomenon, which is sometimes seen from the summit of one of the Hartz Mountains in Hanover, which is about 3300 feet above the level of the sea, and overlooks all the country fifteen miles round. From this mountain the most gigantic and terrific spectres have been seen, which have terrified the credulous, and gratified the curious, in a very high degree. M. Hawe, who witnessed this phenomenon, says the sun rose about four o'clock, after he had ascended to the summit, in a serene sky, free of clouds; and, about quarter past five, when looking round to see if the sky continued clear, he suddenly beheld, at a little distance, a human figure of *a monstrous size* turned towards him, and glaring at him. While gazing on this gigantic spectre, with a mixture of awe and apprehension, a sudden gust of wind nearly carried off his hat, and he clapped his hand to his head to detain it, when to his great delight, the colossal spectre did the same. He changed his body into a variety of attitudes, all which the spectre exactly imitated, and then suddenly vanished without any apparent cause, and in a short time as suddenly appeared. Being joined by another spectator, after the first visions had disappeared, they kept steadily looking for the aerial spectres, when two gigantic monsters suddenly appeared. These spectres had been long considered as preternatural by the inhabitants of the adjacent districts, and the whole country had been filled with awe and terror. Some of the lakes of Ireland are found to be susceptible of producing illusions, particularly the Lake of *Killarney*. This romantic sheet of water is bounded on one side by a semicircle of rugged mountains, and on the other

by a flat morass; and the vapours generated in the marsh, and broken by the mountains, continually represent the most fantastic objects. Frequently men riding along the shore are seen as if they were moving across the lake, which is supposed to have given rise to the legend of O'Donougho, a magician who is said to be visible on the lake every May morning.

There can be little doubt that most of those visionary appearances which have been frequently seen in the sky and in mountainous regions, are phantoms produced by the cause to which I am adverting, such as armies of footmen and horsemen, which some have asserted to have been seen in the air near the horizon. A well-authenticated instance of this kind occurred in the highlands of Scotland: Mr. Wren, of Wetton Hall, and D. Stricket, his servant, in the year 1744, were sitting at the door of the house in a summer evening, when they were surprised to see opposite to them, on the side of Sonterfell hill—a place so extremely steep that scarce a horse could *walk* slowly along it—the figure of a man with a dog pursuing several horses, all running at a most rapid pace. Onward they passed, till at last they disappeared at the lower end of the Fell. In expectation of finding the man dashed to pieces by so tremendous a fall, they went early next morning and made a search, but no trace of man or horse, or the prints of their feet on the turf could be found. Some time afterward, about seven in the evening, on the same spot, they beheld a troop of horsemen advancing in close ranks and at a brisk pace. The inmates of every cottage for a mile round beheld the wondrous scene, though they had formerly ridiculed the story told by Mr. Wren and his servant, and were struck with surprise and fear. The figures were seen for upward of two hours, till the approach of darkness rendered them invisible. The various evolutions and changes through which the troops passed were distinctly visible, and were marked by all the observers. It is not improbable that these aerial troopers were produced by the same cause which made the castle of Dover to appear on the side of the hill next to Ramsgate, and it is supposed that they were images of a body of rebels, on the other side of the hill, exercising themselves previous to the rebellion in 1745.*

I shall mention only another instance of this description which lately occurred in France, and for a time caused a powerful sensation among all ranks. On Sunday, the 17th of December, 1826, the clergy in the parish of Migne, in the vicinity of Poictiers, were engaged in the exercises of the Jubilee which preceded the festival of Christmas, and a number of persons, to the amount of 3000 souls assisted in the service. They had planted, as part of the ceremony, a large cross, twenty-five feet high, and painted red, in the open air beside the church. While one of the preachers, about five in the evening, was addressing the multitude, he reminded them of the miraculous cross which appeared in the sky to Constantine and his army, and the effect it produced, when suddenly a similar celestial cross appeared in the heavens just before the porch of the church, about 200 feet above the horizon, and 140 feet in length, and its breadth from three to four feet, of a bright silver colour, tinged with red. The curate and congregation fixed their wondering gaze upon this extraordinary phenomenon, and the effect produced on the minds of the assembly was strong and solemn; they spontaneously threw themselves on their knees; and many, who had been remiss in their religious duties, humbly confessed their sins, and made vows of penance and reformation. A commission was appointed to investigate the truth of this extraordinary appearance, and a memorial stating the above and other facts, was subscribed by more than forty persons of rank and intelligence, so that no doubt was entertained as to the reality of the phenomenon. By many it was considered as strictly miraculous, as having happened at the time and in the circumstances mentioned. But it is evident, from what we have already stated, that it may be accounted for on physical principles. The large cross of wood painted red was doubtless the real object which produced the magnified image. The state of the atmosphere, according to the descriptions given in the memorial, must have been favourable for the production of such images. The spectrum of the wooden cross must have been cast on the concave surface of some atmospheric mirror, and so reflected back to the eyes of the spectators from an opposite place, retaining exactly the same shape and proportions, but dilated in size; and, what is worthy of attention, it was tinged with red, the very colour of the object of which it was the reflected image.

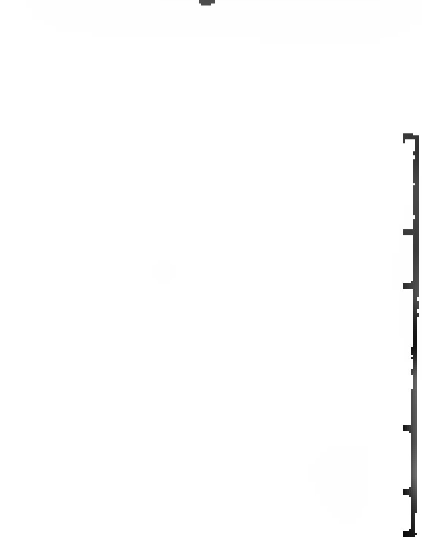
Such phenomena as we have now described, and the causes of them which science is able to unfold, are worthy of consideration, in order to divest the mind of superstitious terrors, and enable it clearly to perceive the laws by which the Almighty directs the move-

* There can be little doubt that some of the facts ascribed, in the western highlands of Scotland, to *second sight*, have been owing to the unusual refraction of the atmosphere; as one of the peculiarities attributed to those who possessed this faculty was, that they were enabled to descry boats and ships before they appeared in the horizon.

ments of the material system. When any appearance in nature, exactly the reverse of every-thing we could have previously conceived, presents itself to view, and when we know of no material cause by which it could be produced, the mind must feel a certain degree of awe and terror, and will naturally resort to supernatural agency as acting either in opposition to the established laws of the universe, or beyond the range to which they are confined. Besides the fears and apprehensions to which such erroneous conceptions give rise, they tend to convey false and distorted impressions of the attributes of the Deity, and of His moral government. Science, therefore, performs an invaluable service to man, by removing the cause of superstitious alarms, by investigating the laws and principles which operate in the physical system, and by assigning reasons for those occasional phenomena which at first sight appeared beyond the range of the operation of natural causes.

The late ingenious Dr. Wollaston illustrated the causes of some of the phenomena we have described, in the following manner: He looked along the side of a red-hot poker at a word or object ten or twelve feet distant; and at a distance less than three-eighths of an inch from the line of the poker, an *inverted* image was seen, and within and without that image, an *erect* image, in consequence of the change produced, by the heat of the poker, in the density of the air. He also suggested the following experiment as another illustration of the same principle, namely, on viewing an object through a stratum of spirit of wine lying above water, or a stratum of water laid above one of syrup. He poured into a *square* vial a small quantity of clear syrup, and above this he poured an equal quantity of *water*, which, gradually combined with the syrup, as seen at *A*, fig. 30. The word "Syrup," on a card held behind the bottle appeared erect when seen through the pure spirit, but inverted when seen through the mixture of water and syrup. He afterward put nearly the same quantity of rectified spirits of wine above the water, as seen at *B*, and he saw the appearance as represented, namely, the true place of the word "Spirit," and the inverted and erect images below. These substances, by their gradual incorporation, produce refracting power, diminishing from the *spirit of wine* to the *water*, or from the *syrup* to the *water*; so that, by looking through the mixed stratum, an inverted image of any object is seen behind the bottle. These experiments show that the *mirage* and several other atmospherical phenomena may be produced by variations in the refractive power of different strata of the atmosphere.

Fig. 30.



It is not unlikely that phenomena of a new and different description from any we have hitherto observed, may be produced from the same causes to which we have adverted. A certain optical writer remarks: "If the variation of the refractive power of the air takes place in a horizontal line perpendicular to the line of vision, that is, from right to left, then we may have a *lateral* mirage, that is, an image of a ship may be seen on the right or left hand of the real ship, or on both, if the variation of refractive power is the same on each side of the line of vision, and a fact of this kind was once observed on the Lake of Geneva. If there should happen at the same time both a vertical and a lateral variation of refractive power in the air, and if the variation should be such as to expand or elongate the object in both directions, then the object would be magnified as if seen through a telescope, and might be seen and recognized at a distance at which it would otherwise have been visible. If the refracting power, on the contrary, varied so as to construct the object in both directions, the image of it would be diminished as if seen through a concave lens."

### *Remarks and Reflections in reference to the Phenomena described above.*

Such, then, are some of the striking and interesting effects produced by the refraction and the reflection of the rays of light. As the formation of the *images* of objects by convex lenses lays the foundation of the construction of refracting telescopes and microscopes, and of all the discoveries they have brought to light, so the property of *concave specula*, in forming similar images, is that on which the construction of *reflecting* telescopes entirely depends. To this circumstance Herschel was indebted for the powerful telescopes he was enabled to construct—which were all formed on the principle of reflection—and for all the discoveries they enabled him to make in the planetary system, and in the sidereal heavens. The same principles which operate in optical instruments, under the agency of man, we have reason to believe frequently

act on a more expansive scale in various parts of the system of nature. The magnificent *cross* which astonished the preacher and the immense congregation assembled at Migné, was, in all probability, caused by a vast atmospherical speculum formed by the hand of nature, and representing its objects on a scale far superior to that of human art; and probably to the same cause is to be attributed the singular phenomenon of the coast of France having been made to appear within two or three miles of the town of Hastings, as formerly described, (see p. 28.) Many other phenomena which we have never witnessed, and of which we can form no conception, may be produced by the same cause operating in an infinity of modes.

The facts we have stated above, and the variety of modes by which light may be refracted and reflected by different substances in nature, lead us to form some conceptions of the magnificent and diversified scenes which light may produce in other systems and worlds under the arrangements of the all-wise and beneficient Creator. Light, in all its modifications and varieties of colour and reflection, may be considered as the beauty and glory of the universe, and the source of unnumbered enjoyments to all its inhabitants. It is a symbol of the Divinity himself; for "God is Light, and in Him is no darkness at all." It is a representative of Him who is exhibited in the sacred oracles as "The Sun of Righteousness," and "the Light of the world." It is an emblem of the glories and felicities of that future world where knowledge shall be perfected and happiness complete; for its inhabitants are designated "the saints in *light*;" and it is declared in sacred history to have been the first-born of created beings. In our lower world, its effects on the objects which surround us, and its influences upon all sensitive beings, are multifarious and highly admirable. While passing from infinitude to infinitude, it reveals the depth and immensity of the heavens, the glory of the sun, the beauty of the stars, the arrangements of the planets, the rainbow encompassing the sky with its glorious circle, the embroidery of flower, the rich clothing of the meadows, the valleys standing thick with corn, "the cattle on a thousand hills," the rivers rolling through the plains, and the wide expanse of the ocean. But in other worlds the scenes it creates may be far more resplendent and magnificent. This may depend upon the refractive and reflective powers with which the Creator has endowed the atmospheres of other planets, and the peculiar constitution of the various objects with which they are connected. It is evident, from what we already know of the reflection of light, that very slight modifications of certain physical principles, and very slight additions to the arrangements of our terrestrial system, might produce scenes of beauty, magnificence, and splendour of which at present we can form no conception. And it is not unlikely that by such diversities of arrangement in other worlds *an infinite variety* of natural scenery is produced throughout the universe.

In the arrangements connected with the planet Saturn, and the immense rings with which it is encompassed, and in the various positions which its satellites daily assume with regard to one another, to the planet itself, and to these rings, there is, in all probability, a combination of refractions, reflections, light, and shadows, which produce scenes wonderfully diversified, and surpassing in grandeur what we can now distinctly conceive. In the remote regions of the heavens there are certain bodies composed of immense masses of luminous matter, not yet formed into any regular system, and which are known by the name of *nebulæ*. What should hinder us from supposing that certain exterior portions of those masses form speculums of enormous size, as some parts of our atmosphere are sometimes found to do? Such specula may be conceived to be hundreds and even thousands of miles in diameter, and that they may form images of the most distant objects in the heavens, on a scale of immense magnitude and extent, and which may be reflected, in all their grandeur, to the eyes of intelligences at a vast distance. And, if the organs of vision of such beings be far superior to ours in acuteness and penetrating power, they may thus be enabled to take a survey of an immense sphere of vision, and to descry magnificent objects at distances the most remote from the sphere they occupy. Whatever grounds there may be for such suppositions, it must be admitted that all the knowledge we have hitherto acquired respecting the operation of light, and the splendid effects it is capable of producing, is small indeed, and limited to a narrow circle, compared with the immensity of its range, the infinite modifications it may undergo, and the wondrous scenes it may create in regions of creation to which human eyes have never yet penetrated, and which may present to view objects of brilliancy and magnificence such as "Eye hath not yet seen, nor ear heard, nor hath it entered into the heart of man to conceive."

# CHAPTER V.

## Section 1.

### *On the Colours of Light.*

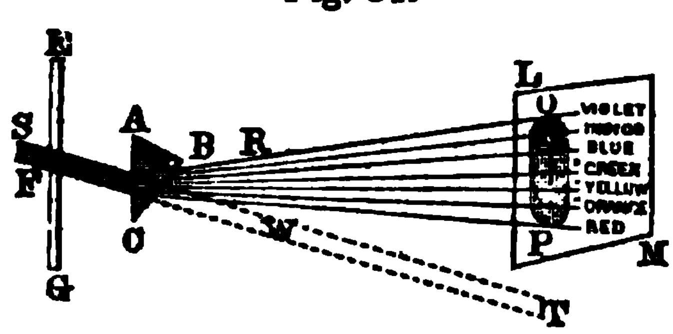
We have hitherto considered light chiefly as a simple homogeneous substance, as if all its rays were white, and as if they were all refracted in the same manner by the different lenses on which they fall. Investigations, however, into the nature of this wonderful fluid have demonstrated that this is not the case, and that it is possessed of certain additional properties of the utmost importance in the system of nature. Had every ray of light been a pure white, and incapable of being separated into any other colours, the scene of the universe would have exhibited a very different aspect from what we now behold. One uniform hue would have appeared over the whole face of nature, and one object could scarcely have been distinguished from another. The different shades of verdure which now diversify every landscape, the brilliant colouring of the flowery fields, and almost all the beauties and sublimities which adorn this lower creation would have been withdrawn. But it is now ascertained that every ray of white light is composed of an assemblage of colours, whence proceed that infinite variety of shade and colour with which the whole of our terrestrial habitation is arrayed. Those colours are found not to be in the objects themselves, but in the rays of light which fall upon them, without which they would either be invisible, or wear a uniform aspect. In reference to this point, Goldsmith has well observed: "The blushing beauties of the rose, the modest blue of the violet, are not in the flowers themselves, but in the light that adorns them. Odour, softness, and beauty of figure are their own; but it is light alone that dresses them up in those robes which shame the monarch's glory."

Many strange opinions and hypotheses were entertained respecting colours by the ancients, and even by many modern writers, prior to the time of Sir Isaac Newton. The Pythagoreans called colour the *superficies* of bodies; Plato said that it was a flame issuing from them. According to Zeno, it is the first configuration of matter; and according to Aristotle, it is that which moves bodies actually transparent. Among the moderns, Des Cartes imagined that the difference of colour proceeds from the prevalence of the direct or rotatory motions of the particles of light. Grimaldi, Dechales, and others, thought the differences of colour depended upon the quick or slow vibrations of a certain elastic medium filling the whole universe. Rohault imagined that the different colours were made by the rays of light entering the eye at different angles with respect to the optic axis; and Dr. Hook conceived that colour is caused by the sensation of the oblique or uneven pulse of light; and this being capable of no more than two varieties, he concluded that there could be no more than two primary colours. Such were some of the crude opinions which prevailed before the era of the illustrious Newton, by whose enlightened investigations the true theory of colours was at last discovered. In the year 1666 this philosopher began to investigate the subject, and finding the coloured image of the sun, formed by a glass prism, to be of an oblong, and not of a circular form, as, according to the laws of refraction, it ought to be, he was surprised at the great disproportion between its length and breadth, the former being *five* times the length of the latter; and he began to conjecture that light is not *homogeneal*, but that it consists of rays, some of which are much more refrangible than others. Prior to this period, philosophers supposed that *all* light, in passing out of one medium into another of different density, was *equally* refracted, in the same or like circumstances; but Newton discovered that this is not the fact; but that there are *different species* of light, and that each species is disposed both to suffer a different degree of refrangibility in passing out of one medium into another, and to excite in us the idea of a *different colour* from the rest; and that bodies appear of that colour which arises from the peculiar rays they are disposed to reflect. It is now, therefore, universally acknowledged that the light of the sun, which to us seems perfectly homogeneal and white, is composed of no fewer than *seven* different colours, namely, *Red, Orange, Yellow, Green, Blue, Indigo, and Violet.* A body which appears of a red colour has the property of reflecting the red rays more powerfully than any of the others; a body of a green colour reflects the green rays more copiously than rays of any other colour, and so of the orange, yellow, blue, purple, and violet. A body which is of a *black* colour, instead of reflecting, *absorbs* all, or the greater part of the rays that fall upon it; and, on the contrary, a body that appears

*white* reflects the greater part of the rays indiscriminately, without separating the one from the other.

Before proceeding to describe the experiments by which the above results were obtained, it may be proper to give some idea of the form and effects of the *prism* by which such experiments are made. This instrument is triangular and straight, and generally about three or four inches long. It is commonly made of white glass, as free as possible from veins and bubbles, and other similar defects, and is solid throughout. Its lateral faces, or sides, should be perfectly plane, and of a fine polish. The angle formed by the two faces, one receiving the ray of light that is refracted in the instrument, and the other affording it an issue on its returning into the air, is called the *refracting angle* of the prism, as $A\ C\ B$ (fig. 31.) The manner in which Newton performed his experiments, and established the discovery to which we have alluded is as follows:

Fig. 31.



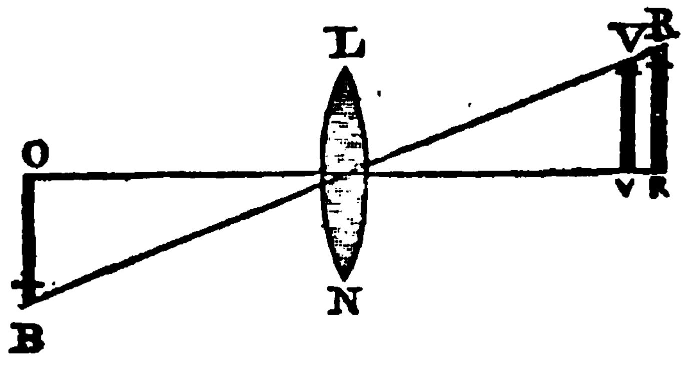

In the window-shutter, $E\ G$ (fig. 31,) of a dark room, a hole, $F$, was made, of about one-third of an inch diameter, and behind it was placed a glass prism, $A\ C\ B$, so that the beam of light, $S\ F$, proceeding directly from the sun, was made to pass through the prism. Before the interposition of the prism, the beam proceeded in a straight line towards $T$, where it formed a round, white spot; but, being now bent out of its course by the prism, it formed an oblong image, $O\ P$, upon the white pasteboard, or screen, $L\ M$, containing the seven colours marked in the figure, the *red* being the *least*, and the *violet* the *most* refracted from the original direction of the solar beam, $S\ T$. This oblong image is called the *prismatic spectrum*. If the refracting angle of the prism, $A\ C\ B$, be 64 degrees, and the distance of the pasteboard from the prism about 18 feet, the length of the image, $O\ P$, will be about ten inches, and the breadth 2 inches. The sides of the spectrum are right lines distinctly bounded, and the ends are semi-circular. From this circumstance, it is evident that it is still the image of the sun, but elongated by the refractive power of the prism. It is evident from the figure that, since some part of the beam, $R\ O$, is refracted much further out of its natural course $W\ T$ than some other part of the beam, as $W\ P$, the rays towards $R\ O$ have a much greater disposition to be refracted than those towards $W\ P$; and that this disposition arises from the naturally different qualities of those rays, is evident from this consideration, that the refracting angle or power of the prism is the same in regard to the superior part of the beam as to the inferior.

By making a hole in the screen, $L\ M$, opposite any one of the colours of the spectrum, so as to allow that colour alone to pass—and by letting the colour thus separated fall upon a second prism—Newton found that the light of each of the colours was alike refrangible, because the second prism could not separate them into an oblong image, or into any other colour. Hence he called all the seven colours *simple* or homogeneous, in opposition to *white* light, which he called *compound*, or heterogeneous. With the prism which this philosopher used, he found the lengths of the colours and spaces of the spectrum to be as follows: Red, 45; Orange, 27; Yellow, 40; Green, 60; Blue, 60; Indigo, 48; Violet, 80; or 360 in all. But these spaces vary a little with prisms formed of different substances, and, as they are not separated by distinct limits, it is difficult to obtain any thing like an accurate measure of their relative extents. Newton examined the ratio between the sines of incidence and refraction of these decompounded rays (see p. 20,) and found that each of the seven primary colour-making rays had certain limits within which they were confined. Thus, let the sine of incidence in glass be divided into 50 equal parts, the sine of refraction into air of the *least* refrangible, and the *most* refrangible rays will contain respectively 77 and 78 such parts. The sines of refraction of all the degrees of *red* will have the intermediate degrees of magnitude, from 77 to 77 one-eighth; *orange*, from 77 one-eighth to 77 one-fifth; *Yellow*, from 77 one-fifth to 77 one-third; *Green*, from 77 one-third to 77 one-half; *Blue*, from 77 one-half to 77 two-thirds; *Indigo*, from 77 two-thirds to 77 seven-ninths; and *Violet*, from 77 seven-ninths to 78.

From what has been now stated, it is evident that, in proportion as any portion of an optic glass bears a resemblance to the form of a prism, the component rays that pass through it must be necessarily separated, and will consequently paint or tinge the object with colours. The edges of every convex lens approach to this form, and it is on this account that the extremities of objects, when viewed through them, are found to be tinged with the prismatic colours. In such a glass, therefore, those different coloured rays will have *different foci*, and will form their re-

spective images at different distances from the lens. Thus, suppose $L\ N$ (fig. 32) to represent

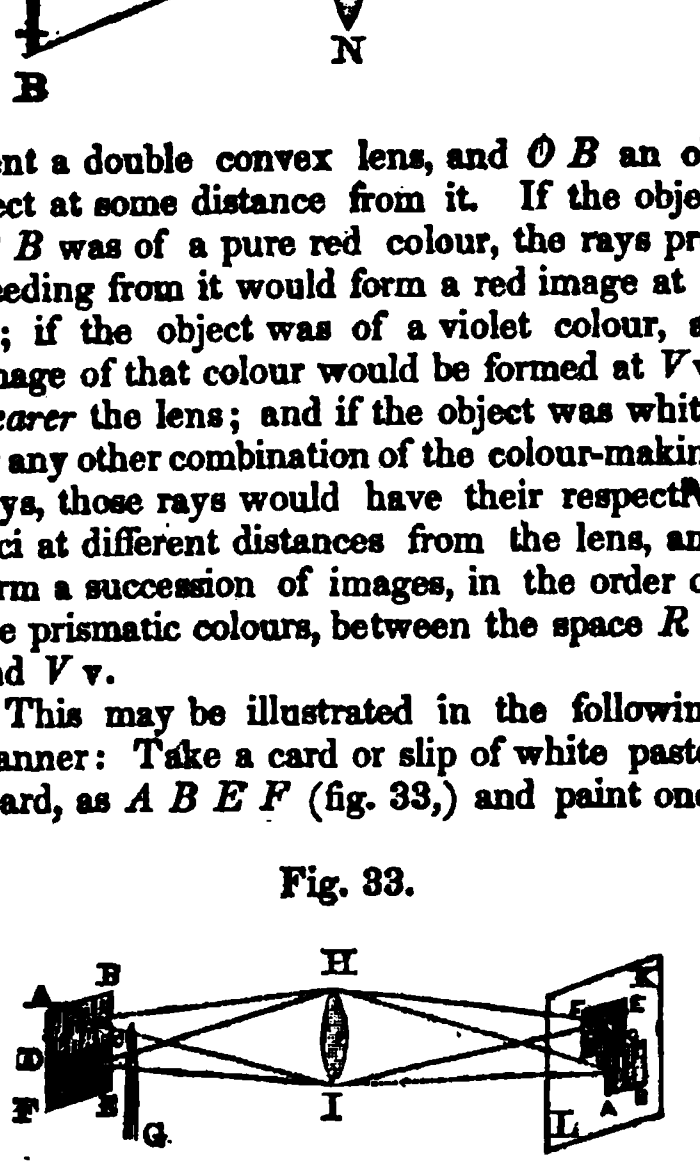
Fig. 32.




sent a double convex lens, and $O\ B$ an object at some distance from it. If the object $O\ B$ was of a pure red colour, the rays proceeding from it would form a red image at $R$ R; if the object was of a violet colour, an image of that colour would be formed at $V$ V; *nearer* the lens; and if the object was white, or any other combination of the colour-making rays, those rays would have their respective foci at different distances from the lens, and form a succession of images, in the order of the prismatic colours, between the space $R$ R and $V$ V.

This may be illustrated in the following manner: Take a card or slip of white pasteboard, as $A\ B\ E\ F$ (fig. 33,) and paint one-

Fig. 33.




half, $A\ B\ C\ D$, *red*, the other half, $C\ F$, *violet* or indigo, and, tying black threads across it, set it near the flame of a candle, $G$; then take a lens, $H\ I$, and, holding a sheet of white paper behind it, move it backward and forward upon the edge of a graduated ruler till you see the black threads most distinctly in the image, and you will find the focus of the violet F E much nearer than that of the red A C, which plainly shows that bodies of different colours can never be depicted by convex lenses without some degree of confusion.

The quantity of dispersion of the coloured rays in convex lenses depends upon the focal length of the glass, the space which the coloured images occupy being about the twenty-eighth part. Thus, if the lens be twenty-eight inches focal distance, the space between $R$ R and $V$ V (fig. 32) will be about one inch; if it be twenty-eight feet focus, the same space will be about one foot, and so on in proportion. Now, when such a succession of images, formed by the different coloured rays, is viewed through an eye-glass, it will seem to form but one image, and, consequently, very indistinct, and tinged with various colours; and as the red figure, $R$ R, is largest, or seen under the greatest angle, the extreme parts of this confused image will be red, and a succession of the prismatic colours will be formed within this red fringe, as is generally found in common refracting telescopes, constructed with a single object-glass. It is owing to this circumstance that the common refracting telescope cannot be much improved without having recourse to lenses of a very long focal distance; and hence, about 150 years ago, such telescopes were constructed of 80, and 100, and 120 feet in length. But still, the image was not formed so distinctly as was desired, and the aperture of the object-glass was obliged to be limited. This is a defect which was long regarded as without a remedy, and even Newton himself despaired of discovering any means by which the defects of refracting telescopes might be removed, and their improvement effected. This, however, was accomplished by Dollond to an extent far surpassing what could have been expected, of which a particular account will be given in the sequel.

It was originally remarked by Newton, and the fact has since been confirmed by the experiments of Sir W. Herschel, that *the different coloured rays have not the same illuminating power.* The violet rays appear to have the least illuminating effect; the indigo more, and the effect increases in the order of the colours, the *green* being very great; between the green and the yellow the greatest of all; the yellow the same as the green; but the red less than the yellow. Herschel also endeavoured to determine whether the power of the differently-coloured rays to *heat* bodies varied with their power to illuminate them. He introduced a beam of light into a dark room, which was decomposed by a prism, and then exposed a very sensible thermometer to all the rays in succession, and observed the heights to which it rose in a given time. He found that their heating power increased from the violet to the red. The mercury in the thermometer rose higher when its bulb was placed in the indigo than when it was placed in the violet, still higher in blue, and highest of all at red. Upon placing the bulb of the thermometer below the red, quite out of the spectrum, he was surprised to find that the mercury rose highest of all, and concluded that *rays proceed from the sun, which have the power of* HEATING but *not of illuminating bodies.* These rays have been called invisible solar rays; they were about half an inch from the commencement of the red rays; at a greater distance from this point the heat began

to diminish, but was very perceptible, even at the distance of 1½ inch. He determined that the heating power of the *red* to that of the *green* rays was 2⅝ to 1, and 3⅓ to 1, in red to *violet*. He afterwards made experiments to collect those invisible caloric rays, and caused them to act independently of the light, from which he concluded that they are sufficient to account for all the effects produced by the solar rays in exciting heat; that they are capable of passing through glass, and of being refracted and reflected, after they have been finally detached from the solar beam.

M. Ritter of Jena, Wollaston, Beckman, and others, have found that the rays of the spectrum are possessed of certain *chemical properties;* that beyond the least brilliant extremity, namely, a little beyond the *violet* ray, there are *invisible* rays, which act chemically, while they have neither the power of heating nor illuminating bodies. Muriate of silver, exposed to the action of the red rays, becomes blackish; a greater effect is produced by the yellow; a still greater by the violet, and the greatest of all by the *invisible* rays *beyond* the violet. When phosphorus is exposed to the action of the invisible rays beyond the red, it emits white fumes, but the invisible rays beyond the violet extinguish them. The influence of these rays is daily seen in the change produced upon vegetable colours, which fade when frequently exposed to the direct influence of the sun. Whatever object they are destined to accomplish in the general economy of nature is not yet distinctly known; we cannot, however, doubt that they are essentially requisite to various processes going forward in the material system. And we know that not only the comfort of all the tribes of the living world, but the very existence of the animal and vegetable creation depends upon the unremitting agency of the *calorific* rays.

It has likewise been lately discovered that certain rays of the spectrum, particularly the *violet, possess the property of communicating the magnetic power.* Mr. *Morichini* of Rome, appears to have been the first who found that the violet rays of the spectrum had this property. The result of his experiments, however, was involved in doubt till it was established by a series of experiments instituted by Mrs. *Somerville*, whose name is so well known in the scientific world. This lady having covered half a sewing-needle, about an inch long, with paper, she exposed the other half for two hours to the violet rays. The needle had then acquired north polarity. The indigo rays produced nearly the same effect; and the blue and green rays produced it in a still less degree. In the yellow, orange, red, and invisible rays no magnetic influence was exhibited, even though the experiment was continued for three successive days. The same effects were produced by inclosing the needle in blue or green glass, or wrapping it in blue or green riband, or half of the needle being always covered with paper.

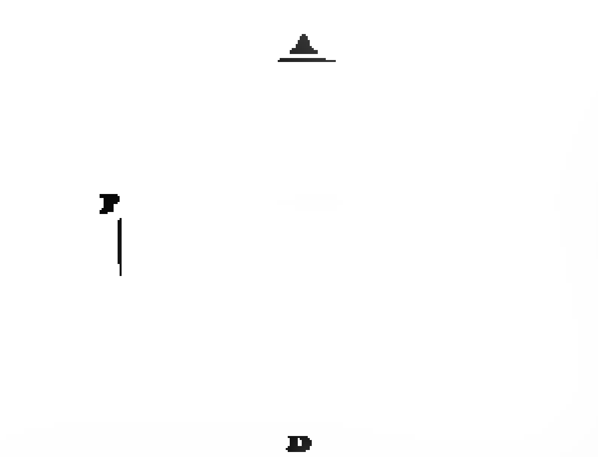
One of the most curious discoveries of modern times, in reference to the solar spectrum, is that of Fraunhofer, of Munich, one of the most distinguished artists and opticians on the Continent.* He discovered that the spectrum is covered with dark and coloured lines, parallel to one another, and perpendicular to the length of the spectrum: and he counted no less than 590 of these lines. In order to observe these lines, it is necessary to use prisms of the most perfect construction, of very pure glass, free of veins, to exclude all extraneous light, and even to stop those rays which form the coloured spaces which we are not examining. It is necessary, also, to use a magnifying instrument, and the light must enter and emerge from the prism at equal angles. One of the important practical results of this discovery is, that those lines are fixed points in the spectrum, or rather, that they have always the same position in the coloured spaces in which they are found. Fraunhofer likewise discovered, in the spectrum produced by the light of Venus, the same streaks as in the solar spectrum; in the spectrum of the light of Sirius he perceived three large streaks, which, according to appearance, had no resemblance to those of the light of the sun; one of them was in the green, two in the blue.

* Fraunhofer was, in the highest sense of the word, an *optician*, an original discoverer in the most abstruse and delicate departments of this science, a competent mathematician, an admirable mechanist, and a man of a truly philosophical turn of mind. By his extraordinary talents, he was soon raised from the lowest station in a manufacturing establishment to the direction of the *optical* department of the business, in which he originally laboured as an ordinary workman. He then applied the whole power of his mind to the perfection of the achromatic telescope, the defects of which, in reference to the optical properties of the materials used, he attempted to remedy; and, by a series of admirable experiments, succeeded in giving to optical determinations the precision of astronomical observations, surpassing in this respect all who had gone before him, except, perhaps, the illustrious Newton. It was in the course of these researches that he was led to the important discovery of the dark lines which occur in the solar spectrum. His achromatic telescopes are scattered over Europe, and are the largest and best that have hitherto been constructed. He died at Munich, at a premature age, in 1826; his death, it is said, being accelerated by the unwholesome nature of the processes employed in his glass-house; leaving behind him a reputation rarely attained by one so young. His memoir "On the refractive and dispersive Power of the different Species of Glass, in reference to the Improvement of Achromatic Telescopes, and an Account of the Lines of the Spectrum," will be found in the "Edinburgh Philosophical Journal," vol. ix. p. 288-299; and vol x. p. 26-40, for 1823-4.

The stars appear to differ from one another in their streaks. The electric light differs very much from the light of the sun and that of a lamp in regard to the streaks of the spectrum. "This experiment may also be made, though in an imperfect manner, by viewing a narrow slit between two nearly closed window-shutters through a very excellent glass prism, held close to the eye, with the refracting angle parallel to the line of light. When the spectrum is formed by the sun's rays, either direct or indirect, as from the sky, clouds, rainbow, moon, or planets, the black bands are always found to be in the same parts of the spectrum, and under all circumstances to maintain the same relative position, breadth, and intensities."

From what has been stated in reference to the solar spectrum, it will evidently appear that white light is nothing else than a compound of all the prismatic colours; and this may be still further illustrated by showing that the seven primary colours, when again put together, recompose white light. This may be rudely proved, for the purpose of illustration, by mixing together seven different powders, having the colours and proportion of the spectrum; but the best mode, on the whole, is the following: Let two circles be drawn on a smooth round board, covered with white paper, as in figure 34; let the outermost be divided

Fig. 34.




into 360 equal parts; then draw seven right lines, as *A*, *B*, *C*, &c., from the centre to the outermost circle, making the lines *A* and *B* include 80 degrees of that circle. The lines *B* and *C*, 40 degrees; *C* and *D*, 60; *D* and *E*, 60; *E* and *F*, 48; *F* and *G*, 27; *G* and *A*, 45. Then between these two circles paint the space *A G* red, inclining to orange near *G*; *G F* orange, inclining to yellow near *F*; *F E* yellow, inclining to green near *E*; *E D* green, inclining to blue near *D*; *D C* blue, inclining to indigo near *C*; *C B* indigo, inclining to violet near *B*; and *B A* violet, inclining to a soft red near *A*. This done, paint all that part of the board black which lies within the inner circle; and, putting an axis through the centre of the board, let it be turned swiftly round that axis, so that the rays proceeding from the above colours may be all blended and mixed together in coming to the eye. Then the whole coloured part will appear like a white ring a little grayish—not perfectly white, because no art can prepare or lay on perfect colours, in all their delicate shades, as found in the real spectrum.

That all the colours of light, when blended together in their proper proportions, produce a pure *white*, is rendered certain by the following experiment: Take a large convex glass, and place it in the room of the paper or screen on which the solar spectrum was depicted (L M, fig. 31;) the glass will unite all the rays which come from the prism, if a paper is placed to receive them, and you will see a circular spot of a pure lively white. The rays will cross each other in the focus of the glass, and, if the paper be removed a little further from that point, you will see the prismatic colours again displayed, but in an inverted order, owing to the crossing of the rays.

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## Section II.

### *On the Colours of Natural Objects.*

From what has been stated above we may learn the true cause of those diversified hues exhibited by natural and artificial objects, and the variegated colouring which appears on the face of nature. It is owing to the surfaces of bodies being disposed to reflect one colour rather than another. When this disposition is such that the body reflects every kind of ray, in the mixed state in which it receives them, that body appears *white* to us, which, properly speaking, is no colour, but rather the assemblage of all colours. If the body has a fitness to reflect one sort of rays more abundantly than others, by absorbing all the others, it will appear of the colour belonging to that species of rays. Thus, the grass is *green*, because it absorbs all the rays except the green. It is these green rays only which the grass, the trees the shrubs, and all the other verdant parts of the landscape reflect to our sight, and which make them appear green. In the same manner, the different flowers reflect their respective colours; the rose, the red rays; the violet, the blue; the jonquil, the yellow; the marigold, the orange; and every object, whether natural or artificial, appears of that colour which its peculiar texture is fitted to reflect. A great

number of bodies are fitted to reflect at once several kinds of rays, and, of consequence, they appear under mixed colours. It may even happen that of two bodies which should be green, for example, one may reflect the pure green of light, and the other the mixture of yellow and blue. This quality, which varies to infinity, occasions the different kinds of rays to unite in every possible manner, and every possible proportion; and hence the inexhaustible variety of shades and hues which nature has diffused over the landscape of the world. When a body absorbs nearly all the light which reaches it, that body appears *black*; it transmits to the eye so few reflected rays that it is scarcely perceptible in itself, and its presence and form make no impression upon us, unless as it interrupts the brightness of the surrounding space. Black is, therefore, the absence of all the coloured rays.

It is evident, then, that all the various assemblages of colours which we see in the objects around us *are not in the bodies themselves*, but in the light which falls upon them. There is no colour *inherent* in the grass, the trees, the fruits, and the flowers, nor even in the most splendid and variegated dress that adorns a lady. All such objects are as destitute of colour, in themselves, as bodies which are placed in the centre of the earth, or as the chaotic materials out of which our globe was formed before light was created; for, where there is no light, there is no colour. Every object is black, or without colour, in the dark, and it only appears coloured as soon as light renders it visible. This is further evident from the following experiment: If we place a coloured body in one of the colours of the spectrum which is formed by the prism, it appears of the colour of the rays in which it is placed. Take, for example, a red rose, and expose it first to the red rays, and it will appear of a more brilliant ruddy hue; hold it in the blue rays, and it appears no longer red, but of a dingy blue colour, and in like manner its colour will appear different when placed in all the other differently-coloured rays. This is the reason why the colours of objects are essentially altered by the nature of the light in which they are seen. The colours of ribands, and various pieces of silk or woollen stuff, are not the same when viewed by candlelight as in the daytime. In the light of a candle or a lamp, blue often appears green, and yellow objects assume a whitish aspect. The reason is, that the light of a candle is not so pure a white as that of the sun, but has a yellowish tinge, and therefore, when refracted by the prism, the yellowish rays are found to predominate, and the superabundance of yellow rays gives to blue objects a greenish hue.

The doctrine we are now illustrating is one which a great many persons, especially among the fair sex, find it difficult to admit. They cannot conceive it possible that there is no colour really inherent in their splendid attire, and no tints of beauty in their countenances. "What," said a certain lady, "are there no colours in my shawl, and in the ribands that adorn my headdress, and are we all as black as negroes in the dark? I should almost shudder to think of it." Such persons, however, need be in no alarm at the idea, but may console themselves with the reflection that, when they are stripped of all their coloured ornaments in the dark, they are certain that *they will never be seen by any one* in that state; and therefore there is no reason to regret the temporary loss of those beauties which light creates, when they themselves, and all surrounding objects, are *invisible*. But, to give a still more palpable proof of this position, the following popular experiments may be stated:

Take a pint of common spirit and pour it into a soup dish, and then set it on fire; as it begins to blaze, throw a handful of salt into the burning spirit, and keep stirring it with a spoon. Several handfuls may thus be successively thrown in, and then the spectators, standing around the flame, will see each other frightfully changed, their colours being altered into a ghastly blackness, in consequence of the nature of the light which falls upon them, which produces colours very different from those of the solar light. The following experiment, as described by Sir D. Brewster, illustrates the same principle: "Having obtained the means of illuminating any apartment with *yellow* light, let the exhibition be made in a room with furniture of various bright colours, and with oil or water-coloured paintings on the wall. The party which is to witness the experiment should be dressed in a diversity of the gayest colours, and the brightest coloured flowers and highly coloured drawings should be placed on the tables. The room being at first lighted with ordinary lights, the bright and gay colours of every thing that it contains will be finely displayed. If the white lights are now suddenly extinguished, and the yellow lamps lighted, the most appalling metamorphosis will be exhibited. The astonished individuals will no longer be able to recognize each other. All the furniture of the room, and all the objects it contains, will exhibit only *one* colour. The flowers will lose their hues; the paintings and drawings will appear as if they were executed in China ink, and the gayest dresses, the brightest scarlets, the purest lilacs, the richest blues, and the most vivid greens, will all be converted into one monotonous yellow. The

complexions of the parties, too, will suffer a corresponding change. One pallid death-like yellow,

> Like the unnatural hue
> Which autumn paints upon the perished leaf,

will envelope the young and the old, and the *sallow* face will alone escape from the metamorphosis. Each individual derives merriment from the cadaverous appearance of his neighbour, without being sensible that he is one of the ghastly assemblage."

From such experiments as these we might conclude that, were the solar rays of a very different description from what they are now found to be, the colours which embellish the face of nature, and the whole scene of our sublunary creation, would assume a new aspect, and appear very different from what we now behold around us in every landscape. We find that the stars display great diversity of colour, which is doubtless owing to the different kinds of light which are emitted from those bodies; and hence we may conclude that the colouring thrown upon the various objects of the universe is different in every different system, and that thus, along with other arrangements, an infinite variety of colouring and of scenery is distributed throughout the immensity of creation.

The *atmosphere*, in consequence of its different refractive and reflective powers, is the source of a variety of colours which frequently embellish and diversify the aspect of our sky. The air *reflects* the blue rays most plentifully, and must therefore *transmit* the red, orange, and yellow more copiously than the other rays. When the sun and other heavenly bodies are at a high elevation, their light is transmitted without any perceptible change; but when they are near the horizon, their light must pass through a long and dense track of air, and must therefore be considerably modified before it reach the eye of the observer. The momentum of the red rays being greater than that of the violet, will force their way through the resisting medium, while the violet rays will be either reflected or absorbed. If the light of the setting sun, by thus passing through a long track of air, be divested of the green, blue, indigo, and violet rays, the remaining rays which are transmitted through the atmosphere will illuminate the western clouds, first, with an orange colour, and then, as the sun gradually sinks into the horizon, the track through which the rays must pass becoming longer, the yellow and orange are reflected, and the clouds grow more deeply *red*, till at length the disappearance of the sun leaves them of a leaden hue, by the reflection of the blue light through the air. Similar changes of colour are sometimes seen on the eastern and western fronts of white buildings. St. Paul's Church, in London, is frequently seen, at sunset, tinged with a very considerable degree of redness; and the same cause occasions the moon to assume a ruddy colour, by the light transmitted through the atmosphere. From such atmospherical refractions and reflections are produced those rich and beautiful hues with which our sky is gilded by the setting sun, and the glowing red which tinges the morning and evening clouds, till their ruddy glare is tempered by the purple of twilight, and the reflected azure of the sky.

When a direct spectrum is thrown on colours darker than itself, it mixes with them, as the yellow spectrum of the setting sun, thrown on the green grass, becomes a greener yellow. But when a direct spectrum is thrown on colours brighter than itself, it becomes instantly changed into the reverse spectrum, which mixes with those brighter colours. Thus the yellow spectrum of the setting sun, thrown on the luminous sky, becomes blue, and changes with the colour or brightness of the clouds on which it appears. The red part of light being capable of struggling through thick and resisting mediums which intercept all other colours, is likewise the cause why the sun appears red when seen through a fog; why distant light, though transmitted through blue or green glass, appears red; why lamps at a distance, seen through the smoke of a long street, are red, while those that are near are white. To the same cause it is owing that a diver at the bottom of the sea is surrounded with the red light which has pierced through the superincumbent fluid, and that the blue rays are reflected from the *surface* of the ocean. Hence Dr. Halley informs us that, when he was in a diving bell at the bottom of the sea, his hand always appeared red in the water.

The *blue* rays, as already noticed, being unable to resist the obstructions they meet with in their course through the atmosphere, are either reflected or absorbed in their passage. It is to this cause that most philosophers ascribe *the blue colour of the sky*, the faintness and obscurity of distant objects, and the bright azure which tinges the mountains of a distant landscape.

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## Section III.

### *Phenomena of the Rainbow.*

Since the rays of light are found to be decomposed by refracting surfaces, and reflected in an infinite variety of modes and shades of colour, we need not be surprised at the changes

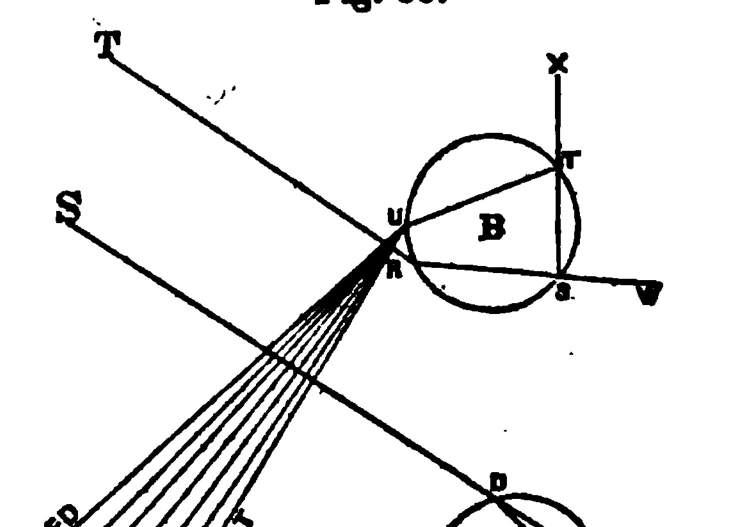
produced in any scene or object by the intervention of another, and by the numerous modifications of which the primary colours of nature are susceptible. The vivid colours which gild the rising and the setting sun must necessarily differ from those which adorn its noonday splendour. Variety of atmospheric scenery will thus necessarily be produced, greater than the most lively fancy can well imagine. The clouds will sometimes assume the most fantastic forms, and at other times will be irradiated with beams of light, or, covered with the darkest hues, will assume a lowering aspect, prognostive of the thunder's roar and the lightning's flash, all in accordance with the different rays that are reflected to our eyes, or the quantity absorbed by the vapours which float in the atmosphere.

Light, which embellishes with so much magnificence a pure and serene sky, by means of innumerable bright starry orbs which are spread over it, sometimes, in a dark and cloudy sky, exhibits an ornament which, by its pomp, splendour, and variety of colours, attracts the attention of every eye that has an opportunity of beholding it. At certain times, when there is a shower either around us, or at a distance from us in an opposite quarter to that of the sun, a species of arch or bow is seen in the sky, adorned with all the seven primary colours of light. This phenomenon, which is one of the most beautiful meteors in nature, has obtained the name of the RAINBOW. The rainbow was, for ages, considered as an inexplicable mystery, and by some nations it was adored as a deity. Even after the dawn of true philosophy, it was a considerable time before any discovery of importance was made as to the true causes which operate in the production of this phenomenon. About the yeaı 1571, M. Fletcher, of Breslau, made a certain approximation to the discovery of the true cause, by endeavouring to account for the colours of the rainbow by means of a double refraction and one reflection. A nearer approximation was made by Antonio de Dominis, bishop of Spalatro, about 1601. He maintained that the double refraction of Fletcher, *with an intervening reflection*, was sufficient to produce the colours of the bow, and also to bring the rays that formed them to the eye of the spectator, without any subsequent reflection. To verify this hypothesis, he procured a small globe of solid glass, and viewing it when it was exposed to the rays of the sun, with his back to that luminary, in the same manner as he had supposed the drops of rain were situated with respect to them, he observed the same colours which he had seen in the rainbow. and in the same order. But he could give no good reason *why* the bow should be coloured. and, much less, any satisfactory account of the *order* in which the colours appear. It was not till Sir I. Newton discovered the different refrangibility of the rays of light that a complete and satisfactory explanation could be given of all the circumstances connected with this phenomenon.

As the full elucidation of this subject involves a variety of optical and mathematical investigations, I shall do little more than explain the general principle on which the prominent phenomena of the rainbow may be accounted for, and some of the facts and results which theory and observation have deduced.

We have just now alluded to an experiment with a glass globe: If, then, we take either a solid glass globe, or a hollow globe filled with water, and suspend it so high in the solar rays above the eye that the spectator, with his back to the sun, can see the globe *red;* if it be lowered slowly, he will see it orange, then yellow, then green, then blue, then indigo, and then violet; so that the drop, at different heights, shall present to the eye the seven primitive colours in succession. In this case, the globe, from its form, will act in some measure like a prism, and the ray will be separated into its component parts. The following figure will more particularly illustrate this point. Suppose *A* (fig. 35) to

Fig. 35.




represent a drop of rain—which may be considered as a globe of glass in miniature, and will produce the same effect on the rays of light —and let *S* D represent a ray from the sun falling upon the upper part of the drop at D. At the point of entering the drop it will suffer a refraction, and, instead of going forward to C, it will be bent to N. From N a part of the light will be reflected to Q—some part of it will, of course, pass through the drop. By the obliquity with which it falls on the side

of the drop at Q, that part becomes a kind of prism, and separates the ray into its primitive colours. It is found by computation, that after a ray has suffered two refractions and one reflection, as here represented, the least refrangible part of it, namely, the *red* ray, will make an angle with the incident solar ray of 42° 2′, as *S* r Q; and the violet, or greatest refrangible ray, will make, with the solar ray, an angle of 40° 17′, as *S* c Q; and thus all the particles of water within the difference of those two angles, namely, 1° 40′ (supposing the ray to proceed merely from the centre of the sun,) will exhibit severally the colours of the prism, and constitute the *interior* bow of the cloud. This holds good at whatever height the sun may chance to be in a shower of rain. If he be at a high altitude, the rainbow will be low; if he be at a low elevation, the rainbow must be high; and if a shower happen in a vale, when the spectator is on a mountain, he will sometimes see the bow in the form of a *complete circle* below him. We have at present described the phenomena only of a single drop; but it is to be considered that in a shower of rain there are drops at all heights and at all distances, and therefore the eye situated at e will see all the different colours. All those drops that are in a certain position with respect to the spectator will reflect the red rays, all those in the next station the orange, those in the next the green, and so on with regard to all the other colours.

It appears, then, that the first or primary bow is formed by two refractions and one reflection; but there is frequently a second bow on the outside of the other, which is considerably fainter. This is produced by drops of rain above the drop we have supposed at *A*. If *B* (fig. 35) represent one of these drops, the ray to be sent to the eye enters the drop near the bottom, and suffers *two refractions* and *two reflections*, by which means the colours become reversed, that is, the violet is lowest in the *exterior* bow, and the red is lowest in the *interior* one, and the other colours are reversed accordingly. The ray *T* is refracted at R: a part of it is reflected from s to T, and at T it suffers another reflection from T to V. At the points s and T part of the ray *passes through* the drop, on account of its transparency, towards W and X, and therefore we say that *part* only of the ray is reflected. By these losses and reflections the exterior bow becomes faint and ill-defined in comparison of the interior or primary bow. In this case the upper part of the secondary bow will not be seen when the sun is above 54° 10′ above the horizon, and the lower part of the bow will not be seen when the sun is 60° 58′ above the horizon.



For the further illustrations of this subject, we may introduce the following section of a a bow (fig. 36,) and, in order to prevent confusion in attempting to represent all the different colours, let us suppose only three drops of rain, and three different colours, as shown in the figure.

Fig. 36.

The spectator, *O*, being in the centre of the two bows here represented—the planes of which must be considered as perpendicular to his view—the drops *A*, *B*, and *C* produce part of the interior bow by two refractions and one reflection, as stated before, and the drops *D*, *E*, *F* will produce the exterior bow by two refractions and two reflections, the sun's rays being represented by 3, 3. It is evident that the angle *C O P* is less than the angle *B O P*, and that the angle *A O P* is the greatest of the three. The largest angle, then, is formed by the red rays, the middle one consists of the green, and the smallest the purple or violet. All the drops of rain, therefore, that happen to be in a certain position with respect to the spectator's eye, will reflect the red rays, and form a band or semicircle of red, and so of the other colours from drops in other positions. If the spectator alters his station, he will see a bow, but not the same as before; and if there be many spectators, they will each see a different bow, though it appears to be the same.

The rainbow assumes a *semicircular* appearance, because it is only at certain angles that the refracted rays are visible to our eyes, as is evident from the experiment of the glass globe formerly alluded to, which will refract the rays only in a certain position. We have already stated that the red rays make an angle of 42° 2′, and the violet an angle of 40°

17′. Now, if a line be drawn horizontally from the spectator's eye, it is evident that angles formed with this line, of a certain dimension, in every direction, will produce a circle, as will appear by attaching a cord of a given length to a certain point, round which it may turn as round its axis; and, in every point, will describe an angle with the horizontal line of a certain and determinate extent.

Sometimes it happens that *three* or more bows are visible, though with different degrees of distinctness. I have more than once observed this phenomenon, particularly in Edinburgh, in the month of August, 1825, when three rainbows were distinctly seen in the same quarter of the sky, and, if I recollect right, a fragment of a fourth made its appearance. This happens when the rays suffer a third or fourth reflection; but on account of the light lost by so many reflections, such bows are, for the most part, altogether imperceptible.

If there were no ground to intercept the rain and the view of the observer, the rainbow would form a *complete circle*, the centre of which is diametrically opposite to the sun. Such circles are sometimes seen in the spray of the sea or of a cascade, or from the tops of lofty mountains, when the showers happen in the vales below. Rainbows of various descriptions are frequently observed rising amid the spray and exhalations of waterfalls, and among the waves of the sea, whose tops are blown by the wind into small drops. There is one regularly seen when the sun is shining, and the spectator in a proper position, at the fall of Staubback, in the bosom of the Alps; one near Schaffhausen; one at the cascade of Lauffen, and one at the cataract of Niagara in North America. A still more beautiful one is said to be seen at Terni, where the whole current of the River Velino, rushing from a steep precipice of nearly 200 feet high, presents to the spectator below a variegated circle, overarching the fall, and two other bows suddenly reflected on the right and left. Don Ulloa, in the account of his journeys in South America, relates that circular rainbows are frequently seen on the mountains above Quito in Peru. It is said that a rainbow was once seen near London, caused by the exhalations of that city, after the sun had been below the horizon more than twenty minutes.* A naval friend, says Mr. Bucke, informed me that, as he was one day watching the sun's effect upon the exhalations near Juan Fernandez, he saw upward of five-and-twenty *ires marinæ* animate the sea at the same time. In these marine bows the concave sides were turned upward, the drops of water rising from below, and not falling from above, as in the instances of the aerial arches. Rainbows are also occasionally seen on the grass in the morning dew, and likewise when the hoarfrost is descending. Dr. Langwith once saw a bow lying on the ground, the colours of which were almost as lively as those of a common rainbow. It was not round, but oblong, and was extended several hundred yards. The colours took up less space, and were much more lively in those parts of the bow which were near him than in those which were at a distance. When M. Labillardiere was on Mount Teneriffe, he saw the contour of his body traced on the clouds beneath him in all the colours of the solar bow. He had previously witnessed this phenomenon on the Kesrouan, in Asia Minor. The rainbows of Greenland are said to be frequently of a pale white, fringed with a brownish yellow, arising from the rays of the sun being reflected from a frozen cloud.

The following is a summary view of the principal facts which have been ascertained respecting the rainbow: 1. The rainbow can only be seen when it rains, and in that point of the heavens which is opposite to the sun. 2. Both the primary and secondary bows are variegated with all the prismatic colours—the red being the highest colour in the primary, or brightest bow, and the violet the highest in the exterior. 3. The primary rainbow can never be a greater arc than a semicircle; and, when the sun is set, no bow, in ordinary circumstances, can be seen. 4. The breadth of the inner or primary bow—supposing the sun but a point—is 1° 45′, and the breadth of the exterior bow 3° 12′, which is nearly twice as great as that of the other; and the distance between the bows is 8° 55′. But since the body of the sun subtends an angle of about half a degree, by so much will each bow be increased, and their distance diminished; and therefore the breadth of the interior bow will be 2° 15′, and that of the exterior 3° 42′, and their distance 8° 25′. The greatest semidiameter of the interior bow, on the same grounds, will be 42° 17′, and the least of the exterior bow 50° 43′. 5. When the sun is in the horizon, either in the morning or evening, the bows will appear complete semicircles. On the other hand, when the sun's altitude is equal to 42° 2′, or to 54° 10′, the summits of the bows will be depressed below the horizon. Hence, during the days of summer, within a certain interval each day, no visible rainbows can be formed, on account of the sun's high altitude above the horizon. 6. The altitude of the bows above the horizon or surface of the earth varies according to the elevation of the sun. The altitude, at any time, may be taken by a common quadrant, or any other angular instrument; but if the sun's altitude at any particular time be known, the height

* Philosophical Transactions, vol. l. p. 294.

of the summit of any of the bows may be found by subtracting the sun's altitude from 42° 2′ for the inner bow, and from 54° 10′ for the outer. Thus, if the sun's altitude be 26°, the height of the primary bow would be 16° 2′, and of the secondary, 28° 10′. It follows that the height and the size of the bows diminish as the altitude of the sun increases. 7. If the sun's altitude is more than 42°, and less than 54°, the exterior bow may be seen, though the interior bow is invisible. 8. Sometimes only a portion of an arch will be visible, while all the other parts of the bow are invisible. This happens when the rain does not occupy a space of sufficient extent to complete the bow; and the appearance of this position, and even of the bow itself, will be various, according to the nature of the situation, and the space occupied by the rain.

The appearance of the rainbow may be produced by artificial means at any time when the sun is shining and not too highly elevated above the horizon. This is effected by means of artificial fountains, or *jet d'eaus*, which are intended to throw up streams of water to a great height. These streams, when they spread very wide, and blend together in their upper parts, form, when falling, a shower of artificial rain. If, then, when the fountain is playing, we move between it and the sun, at a proper distance from the fountain, till our shadow point directly towards it, and look at the shower, we shall observe the colours of the rainbow strong and vivid; and, what is particularly worthy of notice, the bow appears, notwithstanding the nearness of the shower, to be as large and as far off as the rainbow which we see in a natural shower of rain. The same experiment may be made by candle-light, and with any instrument that will form an artificial shower.

*Lunar Rainbows.*—A lunar bow is sometimes formed at night, by the rays of the moon striking on a rain-cloud, especially when she is about the full. But such a phenomenon is very rare. Aristotle is said to have considered himself the first who had seen a lunar rainbow. For more than a hundred years prior to the middle of the last century, we find only two or three instances recorded in which such phenomena are described with accuracy. In the Philosophical Transactions for 1783, however, we have an account of three having been seen in one year, and all in the same place, but they are by no means common phenomena. I have had an opportunity within the last twenty years of witnessing two phenomena of this description, one of which was seen at Perth, on a Sabbath evening, in the autumn of 1825, and the other at Edinburgh, on Wednesday, the 9th of September, 1840, about eight o'clock in the evening, of both which I gave a detailed description in some of the public journals. The moon, in both cases, was within a day or two of the full; the arches were seen in the northern quarter of the heavens, and extended nearly from east to west, the moon being not far from the southern meridian. The bows appeared distinct and well defined, but no distinct traces of the prismatic colours could be perceived on any of them. That which appeared in 1825 was the most distinctly formed, and continued visible for more than an hour. The other was much fainter, and lasted little more than half an hour, dark clouds having obscured the face of the moon. These bows bore a certain resemblance to some of the luminous arches which sometimes accompany the Aurora Borealis, and this latter phenomenon has not unfrequently been mistaken for a lunar rainbow; but they may be always distinguished by attending to the phases and position of the moon. If the moon be not visible above the horizon, if she be in her first or last quarter, or if any observed phenomenon be not in a direction opposite to the moon, we may conclude with certainty that, whatever appearance is presented, there is no lunar rainbow.

The rainbow is an object which has engaged universal attention, and its beautiful colours and form have excited universal admiration. The poets have embellished their writings with many beautiful allusions to this splendid meteor; and the playful schoolboy, while viewing the "bright enchantment," has frequently run "to catch the falling glory." When its arch rests on the opposite sides of a narrow valley, or on the summits of two adjacent mountains, its appearance is both beautiful and grand. In all probability, its figure first suggested the idea of *arches*, which are now found of so much utility in forming aqueducts and bridges, and for adorning the architecture of palaces and temples. It is scarcely possible seriously to contemplate this splendid phenomenon without feeling admiration and gratitude towards that wise and beneficent Being whose hands have bent it into so graceful and majestic a form, and decked it with all the pride of colours. "Look upon the rainbow," says the son of Sirach,* "and praise Him that made it: very beautiful it is in the brightness thereof. It compasseth the heaven about with a glorious circle, and the hands of the Most High have bended it." To this grand ethereal bow the inspired writers frequently allude as one of the emblems of the majesty and splendour of the Almighty. In the prophecies of Ezekiel, the throne of Deity is represented as adorned with a brightness "like the appearance of the bow that is in the cloud in the day of rain—the

* Ecclesiasticus, xliii. 11, 12.

appearance of the likeness of the glory of Jehovah." And, in the visions recorded in the Book of the Revelations, where the Most High is represented as sitting upon a throne, "there was a rainbow round about the throne, in sight like unto an emerald," as an emblem of his propitious character, and of his faithfulness and mercy. After the deluge, this bow was appointed as a sign and memorial of the covenant which God made with Noah and his sons, that a flood of waters should never again be permitted to deluge the earth and its inhabitants, and as a pledge of inviolable fidelity and Divine benignity. When, therefore, we at any time behold "the bow in the cloud," we have not only a beautiful and sublime phenomenon presented to the eye of sense, but also a memorial exhibited to the mental eye, assuring us that, "While the earth remaineth, seed-time and harvest, and cold and heat, and summer and winter, and day and night, *shall not cease*."*

"On the broad sky is seen
A dewy cloud, and in the cloud a bow
Conspicuous, with seven listed colours gay,
Betokening peace with God and covenant new.
He gives a promise never to destroy
The earth again by flood, nor let the sea
Surpass his bounds, nor rain to drown the world."
MILTON, *Par. Lost, Book XI.*

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## SECTION IV.

### *Reflections on the beauty and utility of Colours.*

Colour is one of the properties of light which constitutes chiefly the beauty and sublimity of the universe. It is colour, in all its diversified shades, which presents to our view that almost infinite variety of aspect which appears on the scene of nature, which gives delight to the eye and the imagination, and which adds a fresh pleasure to every new landscape we behold. Every flower which decks our fields and gardens is compounded of different hues; every plain is covered with shrubs and trees of different degrees of verdure; and almost every mountain is clothed with herbs and grass of different shade from those which appear on the hills and landscape with which it is surrounded. In the country, during summer, nature is every day, and almost every hour, varying her appearance by the multitude and variety of her hues and decorations, so that the eye wanders with pleasure over objects continually diversified, and extending as far as the sight can reach. In the flowers with which every landscape is adorned, what a lovely assemblage of colours, and what a wonderful art in the disposition of their shades! Here a light pencil seems to have laid on the delicate tints; there they are blended according to the nicest rules of art. Although green is the general colour which prevails over the scene of sublunary nature, yet it is diversified by a thousand different shades, so that every species of tree, shrub, and herb is clothed with its own peculiar verdure. The dark green of the forests is thus easily distinguished from the lighter shades of cornfields and the verdure of the lawns. The system of animated nature likewise displays a diversified assemblage of beautiful colours. The plumage of birds, the brilliant feathers of the peacock, the ruby and emerald hues which adorn the little humming-bird, and the various embellishments of many species of the insect tribe, present to the eye, in every region of the globe, a scene of diversified beauty and embellishment. Nor is the mineral kingdom destitute of such embellishments; for some of the darkest and most unshapely stones and pebbles, when polished by the hand of art, display a mixture of the most delicate and variegated colours. All which beauties and varieties in the scene around us are entirely owing to that property, in every ray of light, by which it is capable of being separated into the primitive colours.

To the same cause, likewise, are to be ascribed those beautiful and diversified appearances which frequently adorn the face of the sky—the yellow, orange, and ruby hues which embellish the firmament at the rising of the sun, and when he is about to descend

* It is a question which has been frequently started, Whether there was any rainbow before the flood? Some have conceived that the rainbow was something of a *miraculous* production, and that it was never seen before the flood. The equivocal sense of the word "set," in our translation, has occasioned a mistaken impression of this kind. The Hebrew word, thus translated, signifies more properly "I do give," or "I *appoint*." The whole passage in reference to this circumstance, literally translated, runs thus: "I appoint my bow which is in the cloud, that it may be for a sign or token of a covenant between me and the earth; and it shall come to pass, when I bring a cloud over the earth, and the bow shall be seen in the cloud, that I will remember my covenant that is between me and you," &c. As the rainbow is produced by the immutable laws of refraction and reflection, as applied to the rays of the sun striking on drops of falling rain, the phenomenon must have been occasionally exhibited from the beginning of the world; unless we suppose that there was no rain before the flood, and that the constitution of things in the physical system was very different from what it is now. The passage affirms no more than that the rainbow was *then appointed* to be a *symbol* of the covenant between God and man; and although it may have been frequently seen before, it would serve the purpose of a sign equally well as if it had been miraculously formed for this purpose, and even better, as its frequent appearance, according to natural laws, is a perpetual memorial to man of the Divine faithfulness and mercy.

below the western horizon; and those aerial landscapes, so frequently beheld in tropical climes, where rivers, castles, and mountains are depicted rolling over each other along the circle of the horizon. The clouds, especially in some countries, reflect almost every colour in nature. Sometimes they wear the modest blush of the rose; sometimes they appear like stripes of deep vermilion, and sometimes as large, brilliant masses tinged with various hues; now they are white as ivory, and now as yellow as native gold. In some tropical countries, according to St. Pierre, the clouds roll themselves up into enormous masses as white as snow, and are piled upon each other like the Cordeliers of Peru, and are moulded into the shape of mountains, of caverns, and of rocks. When the sun sets behind this magnificent aerial network, a multitude of luminous rays are transmitted through each particular interstice, which produce such an effect that the two sides of the lozenge illuminated by them have the appearance of being begirt with a fillet of gold; and the other two, which are in the shade, seem tinged with a superb ruddy orange. Four or five divergent streams of light, emanating from the setting sun up to the zenith, clothe with fringes of gold the undeterminate summits of this celestial barrier, and proceed to strike with the reflexes of their fires the pyramids of the collateral aerial mountains, which then appear to consist of silver and vermilion. In short, colour diversifies every sublunary scene, whether on the earth or in the atmosphere; it imparts a beauty to the phenomena of falling stars, of luminous arches, and the coruscations of the Aurora Borealis, and gives a splendour and sublimity to the spacious vault of heaven.

Let us now consider for a moment what would be the aspect of nature if, instead of the beautiful variety of embellishments which now appear on every landscape, and on the concave of the sky, *one* uniform colour had been thrown over the scenery of the universe. Let us conceive the whole of terrestrial nature to be covered with snow, so that not an object on earth should appear with any other hue, and that the vast expanse of the firmament presented precisely the same uniform aspect. What would be the consequence? The light of the sun would be strongly reflected from all the objects within the bounds of our horizon, and would produce a lustre which would dazzle every eye. The day would acquire a greater *brightness* than it now exhibits, and our eyes might, after some time, be enabled freely to expatiate over the surrounding landscape; but every thing, though enlightened, would appear *confused*, and particular objects would scarcely be distinguishable. A tree, a house, or a church near at hand might possibly be distinguished, on account of its elevation above the general surface of the ground, and the bed of a river by reason of its being depressed below it. But we should be obliged rather to guess, and to form a conjecture as to the particular object we wished to distinguish, than to arrive at any certain conclusion respecting it; and if it lay at a considerable distance, it would be impossible, with any degree of probability, to discriminate any one object from another. Notwithstanding the universal brightness of the scene, the uniformity of colour thrown on every object would most certainly prevent us from distinguishing a church from a palace, a cottage from a knoll or heap of rubbish, a splendid mansion from rugged rocks, the trees from the hills on which they grow, or a barren desart from rich and fertile plains. In such a case human beings would be confounded, and even friends and neighbours be at a loss to recognize one another.

The vault of heaven, too, would wear a uniform aspect. Neither planets nor comets would be visible to any eye, nor those millions of stars which now shine forth with so much brilliancy, and diversify the nocturnal sky; for it is by the contrast produced by the deep azure of the heavens and the white radiance of the stars that those bodies are rendered visible. Were they depicted on a pure white ground, they would not be distinguished from that ground, and would, consequently, be invisible, unless any of them occasionally assumed a different colour. Of course, all that beautiful variety of aspect which now appears on the face of sublunary nature—the rich verdure of the fields, the stately port of the forest, the rivers meandering through the valleys, the splendid hues that diversify and adorn our gardens and meadows, the gay colouring of the morning and evening clouds, and all that variety which distinguishes the different seasons, would entirely disappear. As every landscape would exhibit nearly the same aspect, there would be no inducement to the poet and the philosopher to visit distant countries to investigate the scenes of nature, and journeyings from one region to another would scarcely be productive of enjoyment. Were any other single colour to prevail, nearly the same results would ensue. Were a deep ruddy hue to be uniformly spread over the scene of creation, it would not only be offensive to the eye, but would likewise prevent all distinction of objects. Were a dark blue or a deep violet to prevail, it would produce a similar effect, and, at the same time, present the scene of nature as covered with a dismal gloom. Even if creation were arrayed in a robe of *green*,

which is a more pleasant colour to the eye, were it not diversified with the different shades it now exhibits, every object would be equally undistinguishable.

Such would have been the aspect of creation, and the inconveniences to which we should have been subjected, had the Creator afforded us light without that intermixture of colours which now appears over all nature, and which serves to discriminate one object from another. Even our very apartments would have been tame and insipid, incapable of the least degree of ornament, and the articles with which they are furnished almost undistinguishable, so that, in discriminating one object from another, we should have been as much indebted to the sense of touch as to the sense of vision. Our friends and fellow-men would have presented no objects of interest in our daily associations. The sparkling eye, the benignant smile, the modest blush, the blended hues of white and vermilion in the human face, and the beauty of the female countenance, would all have vanished, and we should have appeared to one another as so many moving marble statues, cast nearly in the same mould. But what would have been, worst of all, the numerous delays, uncertainties, and perplexities to which we should have been subjected, had we been under the necessity every moment of distinguishing objects by trains of reasoning, and by circumstances of time, place, and relative position? An artist, when commencing his work in the morning, with a hundred tools of nearly the same size and shape around him, would have spent a considerable portion of his time before he could have selected those proper for his purpose, or the objects to which they were to be applied; and in every department of society, and in all our excursions from one place to another, similar difficulties and perplexities would have occurred. The one half of our time must thus have been employed in uncertain guesses and perplexing reasonings respecting the real nature and individuality of objects, rather than in a regular train of thinking and of employment; and, after all our perplexities and conjectures, we must have remained in the utmost uncertainty as to the thousands of scenes and objects which are now obvious to us, through the instrumentality of colours, as soon as we open our eyes.

In short, without colour we could have had no books nor writings: we could neither have corresponded with our friends by letters, nor have known any thing with certainty of the events which happened in former ages. No written revelation of the will of God, and of his character, such as we now enjoy, could have been handed down to us from remote periods and generations. The discoveries of science and the improvements of art would have remained unrecorded. Universal ignorance would have prevailed throughout the world, and the human mind have remained in a state of demoralization and debasement. All these, and many other inconveniences and evils would have inevitably followed, had not God painted the rays of light with a diversity of colours. And hence we may learn that the most important scenes and events in the universe may depend upon the existence of a single principle in nature, and even upon the most minute circumstances, which we may be apt to overlook, in the arrangements of the material world

In the existing state of things in the visible creation, we cannot but admire the wisdom and beneficence of the Deity in thus enabling us to distinguish objects by so easy and expeditious a mode as *that of colour*, which in a moment discriminates every object and its several relations. We rise in the morning to our respective employments, and our food, our drink, our tools, our books, and whatever is requisite for our comfort, are at once discriminated. Without the least hesitation or uncertainty, and without any perplexing process of reasoning, we can lay our hands on whatever articles we require. Colour clothes every object with its peculiar livery, and infallibly directs the hands in its movements, and the eye in its surveys and contemplations. But this is not the only end which the Divine Being had in view in impressing on the rays of light a diversity of colours. It is evident that he likewise intended to minister to our *pleasures* as well as to our wants. To every man of taste, and almost to every human being, the combination of colours in flowers, the delicate tints with which they are painted, the diversified shades of green with which the hills and dales, the mountains and the vales are arrayed, and that beautiful variety which appears in a bright summer day on all the objects of this lower creation, are sources of the purest enjoyment and delight. It is colour, too, as well as magnitude, that adds to the *sublimity* of objects. Were the canopy of heaven of one uniform hue, it would fail in producing those lofty conceptions, and those delightful and transporting emotions, which a contemplation of its august scenery is calculated to inspire. Colours are likewise of considerable utility in the intercourse of general society. They serve both for ornaments, and for distinguishing the different ranks and conditions of the community; they add to the beauty and gracefulness of our furniture and clothing. At a glance, they enable us at once to distinguish the noble from the ignoble, the prince from his subjects, the master from his servant, and the widow, clothed with sable

weeds, from the bride adorned with her nuptial ornaments.

Since colours, then, are of so much value and importance, they may be reckoned as holding a rank among the noblest natural gifts of the Creator. As they are of such essential service to the inhabitants of our globe, there can be no doubt that they serve similar or analogous purposes throughout all the worlds in the universe. The colours displayed in the solar beams are common to all the globes which compose the planetary system, and must necessarily be reflected, in all their diversified hues, from objects on their surfaces. The light which radiates from the fixed stars displays a similar diversity of colours. Some of the double stars are found to emit light of different hues; the larger star exhibiting light of a ruddy or orange hue, and the smaller one a radiance which approaches to blue or green. There is, therefore, reason to conclude that the objects connected with the planets which revolve round such stars—being occasionally enlightened by suns of different hues—will display a more variegated and splendid scenery of colouring than is ever beheld in the world on which we dwell; and that one of the distinguishing characteristics of different worlds, in regard to their embellishments, may consist in the splendour and variety of colours with which the objects on their surfaces are adorned. In the metaphorical description of the glories of the New Jerusalem, recorded in the Book of Revelation, one of the chief characteristics of that city is said to consist in the splendour and diversity of hues with which it is adorned. It is represented as "coming down from heaven, *prepared as a bride adorned for her husband*," and as reflecting all the beautiful and variegated colours which the finest gems on earth can exhibit; evidently indicating that splendour and variety of colouring are some of the grandest features of celestial scenery.

On the whole, the subject of colours, when seriously considered, is calculated to excite us to the adoration of the goodness and intelligence of that Almighty Being whose wisdom planned all the arrangements of the universe, and to inspire us with gratitude for the numerous conveniences and pleasures we derive from those properties and laws he has impressed on the material system. He might have afforded us light, and even splendid illumination, without the pleasures and advantages which diversified colours now produce, and man and other animated beings might have existed in such a state. But what a very different scene would the world have presented from what it now exhibits! Of how many thousands of pleasures should we have been deprived! and to what numerous inconveniences and perplexities should we have been subjected! The sublimity and glories of the firmament, and the endless beauties and varieties which now embellish our terrestrial system, would have been for ever unknown, and man could have had little or no incitement to study and investigate the works of his Creator. In this, as well as in many other arrangements in nature, we have a sensible proof of the presence and agency of that Almighty Intelligence "in whom we live, and move, and have our being." None but an infinitely Wise and Beneficient Being, intimately present in all places, could thus so regularly create in us, by means of colour, those exquisite sensations which afford so much delight, and which unite us, as it were, with every thing around us. In the diversity of hues spread over the face of creation, we have as real a display of the Divine presence as Moses enjoyed at the burning bush. The only difference is, that the one was out of the common order of Divine procedure, and the other in accordance with those permanent laws which regulate the economy of the universe. In every colour, then, which we contemplate, we have a sensible memorial of the presence of that Being "whose Spirit garnished the heavens and laid the foundations of the earth," and whose "merciful visitation" sustains us every moment in existence. But the revelation of God to our senses, through the various objects of the material world, has become so familiar, that we are apt to forget the Author of all our enjoyments, even at the moment when we are investigating his works and participating of his benefits. "O that men would praise Jehovah for his goodness, and for his wonderful works towards the children of men."

# PART II.

## ON TELESCOPES.

### CHAPTER I.

*History of the Invention of Telescopes.*

The telescope is an optical instrument for viewing objects at a distance. Its name is compounded of two Greek words, τηλε, which signifies *at a distance* or *far off*, and σκοπειν, *to view* or to *contemplate.* By means of telescopes, remote objects are represented as if they were near, small apparent magnitudes are enlarged, confused objects are rendered distinct, and the invisible and obscure parts of very distant scenes are rendered perceptible and clear to the organ of vision. The telescope is justly considered as a grand and noble instrument. It is not a little surprising that it should be in the power of man to invent and construct an instrument by which objects, too remote for the unassisted eye to distinguish, should be brought within the range of distinct vision, as if they were only a few yards from our eye, and that thousands of august objects in the heavens, which had been concealed from mortals for numerous ages, should be brought within the limits of our contemplation, and be as distinctly perceived as if we had been transported many millions of miles from the space we occupy through the celestial regions. The celebrated Huygens remarks, in reference to this instrument, that, in his opinion, "the wit and industry of man has not produced any thing so noble and so worthy of his faculties as this sort of knowledge (namely, of the telescope;) insomuch that if any particular person had been so diligent and sagacious as to invent this instrument from the principles of nature and geometry, for my part, I should have thought his abilities were more than human; but the case is so far from this, that the most learned men have not yet been able sufficiently to explain the reason of the effects of this casual invention."

The persons who constructed the first telescopes, and the exact period when they were first invented, are involved in some degree of obscurity. It does not certainly appear that such instruments were known to the ancients, although we ought not to be perfectly decisive on this point. The cabinets of the curious contain some very ancient gems of admirable workmanship, the figures on which are so small that they appear beautiful through a magnifying glass, but altogether confused and indistinct to the naked eye; and therefore it may be asked, If they cannot be *viewed*, how could they *be wrought*, without the assistance of glasses? And as some of the ancients have declared that the moon has a form like that of the earth, and has plains, hills, and valleys in it, how could they know this, unless by mere conjecture, without the use of a telescope? And how could they have known that the *Milky Way* is formed by the combined rays of an infinite number of stars? For Ovid states, in reference to this zone, "its groundwork is of stars." But, whatever knowledge the ancients may have possessed of the telescope or other optical glasses, it is quite evident that they never had telescopes of such size and power as those which we now possess, and that no discoveries in the heavens, such as are now brought to light, were made by any of the ancient astronomers, otherwise some allusions to them must have been found in their writings.

Among the moderns, the illustrious Friar Bacon appears to have acquired some rude ideas respecting the construction of telescopes. "Lenses and specula," says he, "may be so figured that one object may be multiplied into many, that those which are situated at a great distance may be made to appear very near, that those which are small may be made to appear very large, and those which are obscure very plain; and we can make stars to appear wherever we will." From these expressions, it appears highly probable that this philosopher was acquainted with the general principle both of telescopes and microscopes, and that he may have constructed telescopes of small magnifying power for his own observation and amusement, although they never came into general use. He was a man of extensive learning, and made so rapid a pro-

gress in the sciences, when attending the University of Paris, that he was esteemed the glory of that seat of learning. He prosecuted his favourite study of experimental philosophy with unremitting ardour, and in this pursuit, in the course of twenty years, he expended no less than £2000 in experiments, instruments, and in procuring scarce books. In consequence of such extraordinary talents and such astonishing progress in the sciences in that ignorant age, he was represented, by the envy of his illiterate fraternity, as having dealings with the devil; and, under this pretence, he was restrained from reading lectures, and at length, in 1278, when sixty-four years of age, he was imprisoned in his cell, where he remained in confinement for ten years. He shone like a single bright star in a dark hemisphere—the glory of our country—and died at Oxford, in the year 1294, in the eightieth year of his age. "Friar Bacon," says the Rev. Mr. Jones, "may be considered as the first of English philosophers; his profound skill in mechanics, optics, astronomy, and chemistry would make an honourable figure in the present age. But he is entitled to further praise, as he made all his studies subservient to theology, and directed all his writings, as much as could be, to the glory of God. He had the highest regard for the sacred Scriptures, and was persuaded they contain the principles of all true science."

The next person who is supposed to have acquired a knowledge of telescopes was Joannes Baptista Porta, of Naples, who flourished in the sixteenth century. He discovered the *Camera Obscura*, the knowledge of which might naturally have led to the invention of the telescope; but it does not appear that he ever constructed such an instrument. Des Cartes considers James Metius, a Dutchman, as the first constructor of a telescope, and says that, "as he was amusing himself with making mirrors and burning-glases, he casually thought of looking through two of his lenses at a time, and found that distant objects appeared very large and distinct." Others say that this great discovery was first made by John Lippersheim, a maker of spectacles at Middleburg, or, rather, by his children, who were diverting themselves with looking through two glasses at a time, and placing them at different distances from each other. But Borellus, who wrote a book "on the invention of the telescope," gives this honour to Zacharias Jansen, another spectacle maker in the same town, who, he says, made the first telescope in 1590. Jansen was a diligent inquirer into nature, and, being engaged in such pursuits, he was trying what use could be made of lenses for those purposes, when he fortunately hit upon the construction. Having found the arrangement of glasses which produced the effect desired, he inclosed them in a tube, and ran with his instrument to Prince Maurice, who, immediately conceiving that it might be of use to him in his wars, desired the author to keep it a secret. Such are the rude conceptions and selfish views of princely *warriors*, who would apply every invention in their power for the destruction of mankind. But the telescope was soon destined to more noble and honourable achievements. Jansen, it is said, directed his instrument towards celestial objects, and distinctly saw the spots on the surface of the moon, and discovered many new stars, particularly several pretty considerable ones in the Great Bear. His son Joannes is said to have noticed the lucid circle near the lower limb of the moon, now named *Tycho*, from whence several bright rays seemed to dart in different directions. In viewing Jupiter, he perceived two, sometimes three, and, at the most, four small stars, a little above or below him, and thought that they performed revolutions around him. This was probably the first observation of the satellites of Jupiter, though the person who made it was not aware of the importance of his discovery.*

It is not improbable that different persons about Middleburg hit upon the invention, in different modes, about the same time. Lippersheim seems to have made his first rude telescope by adjusting two glasses on a board, and supporting them on brass circles.† Other workmen, particularly Metius and Jansen, in emulation of each, other, seem to have made use of that discovery, and by the new form they gave it, made all the honour of it their own. One of them, considering the effects of light as injurious to distinctness, placed the glasses in a tube blackened within. The other, still more cautious, placed the same glasses within tubes capable of sliding one in another, both to vary the prospects, by lengthening the instrument, according to the pleasure of the observer, and to render it portable and commodious. Thus it is probable that different persons had a share in the invention, and jointly contributed to its improvement. At any rate, it is undoubtedly to the Dutch that we owe the original invention. The first telescope made by Jansen did not exceed fifteen or sixteen inches in length,

* Though Borellus mentions this circumstance, yet there is some reason to doubt the accuracy of this statement, as young Jansen appears to have been at that period not more than six years old; so that it is more probable that Galileo was the first discoverer of Jupiter's satellites.

† The reader may see an engraving of this instrument in the author's work entitled "*The Improvement of Society*."

and therefore its magnifying power could not have been very great.

The famous Galileo has frequently been supposed to have been the inventor of the telescope, but he acknowledges that he had not the honour of being the original inventor, having first learned from a German that such an instrument had already been made; although, from his own account, it appears that he had actually reinvented this instrument. The following is the account, in his own words, of the circumstances which led him to construct a telescope: "Nearly ten months ago (namely, in April or May, 1609,) it was reported that a certain Dutchman had made a perspective through which many distant objects appeared distinct as if they were near. Several effects of this wonderful instrument were reported, which some believed and others denied; but, having it confirmed to me a few days after by a letter from the noble John Badoverie, at Paris, I applied myself to consider the reason of it, and by what means I might contrive a similar instrument, which I afterward attained to by the doctrine of refractions. And, first, I prepared a leaden tube, to whose extremities I fitted two spectacle-glasses, both of them plane on one side, and on the other side one of them was spherically convex, and the other concave. Then applying my eye to the concave, I saw objects appear pretty large and pretty near me. They appeared three times nearer and nine times larger in surface than to the naked eye; and soon after I made another, which represented objects about sixty times larger, and eight times nearer; and at last, having spared no labour or expense, I made an instrument so excellent as to show things almost a thousand times larger, and above thirty times nearer, than to the naked eye." In another part of his writings, Galileo informs us that "he was at Venice when he heard of Prince Maurice's instrument, but nothing of its construction; that the first night after he returned to Padua he solved the problem, and made his instrument the next day, and soon after presented it to the doge at Venice, who, to do him honour for his grand invention, gave him the ducal letters which settled him for life in his lectureship at Padua; and the Republic, on the 25th of August, in the same year (1610,) more than tripled his salary as professor."

The following is the account which this philosopher gives of the process of reasoning which led him to the construction of a telescope: "I argued in the following manner: The contrivance consists either of one glass or more: one is not sufficient, since it must be either convex, concave, or plane; the last does not produce any sensible alteration in objects, the cancave diminishes them; it is true that the convex magnifies, but it renders them confused and indistinct, consequently, one glass is insufficient to produce the desired effect. Proceeding to consider two glasses, and bearing in mind that the plane glass causes no change, I determined that the instrument could not consist of the combination of a plane glass with either of the other two. I therefore applied myself to make experiments on combinations of the two other kinds, and thus obtained that of which I was in search." If the true inventor is the person who makes the discovery by reasoning and reflection, by tracing facts and principles to their consequences, and by applying his invention to important purposes, then Galileo may be considered as the real inventor of the telescope. No sooner had he constructed this instrument—before he had seen any similar one—than he directed his tube to the celestial regions, and his unwearied diligence and ardour were soon rewarded by a series of new and splendid discoveries. He descried the four satellites of Jupiter, and marked the periods of their revolutions; he discovered the phases of Venus, and thus was enabled to adduce a new proof of the Corpernican system, and to remove an objection that had been brought against it. He traced on the lunar orb a resemblance to the structure of the earth, and plainly perceived the outlines of mountains and vales, casting their shadows over different parts of its surface. He observed that, when Mars was in quadrature, his figure varied slightly from a perfect circle, and that Saturn consisted of a triple body, having a small globe on each side, which deception was owing to the imperfect power of his telescope, which was insufficient to show him that the phenomenon was in reality a ring. In viewing the sun, he discovered large dark spots on the surface of that luminary, by which he ascertained that that mighty orb performed a revolution round its axis. He brought to view multitudes of stars imperceptible to the naked eye, and ascertained that those nebulous appearances in the heavens which constitute the Milky Way consist of a vast collection of minute stars too closely compacted together to produce an impression on our unassisted vision.

The results of Galileo's observations were given to the world in a small work, entitled "*Nuncius Sidereus*," or, "News from the Starry Regions," which produced an extraordinary sensation among the learned. These discoveries soon spread throughout Europe, and were incessantly talked of, and were the cause of much speculation and debate among the circles of philosophers. Many doubted; many positively refused to believe so novel

and unlooked-for announcements, because they ran counter to the philosophy of Aristotle, and all the preconceived notions which then prevailed in the learned world. It is curious, and may be instructive, to consider to what a length of absurdity ignorance and prejudice carried many of those who made pretensions to learning and science. Some tried to reason against the facts alleged to be discovered; others contented themselves, and endeavoured to satisfy others with the simple *assertion* that such things were not, and could not possibly be; and the manner in which they supported themselves in their incredulity was truly ridiculous. "O my dear Kepler," says Galileo, in a letter to that astronomer, "how I wish we could have one hearty laugh together. Here at Padua is the principal professor of philosophy, whom I have repeatedly and urgently requested to look at the moon and planets through my glass, which *he pertinaciously refuses to do*, lest his opinions should be overturned. Why are you not here? what shouts of laughter we should have at this glorious folly! and to hear the professor of philosophy at Pisa labouring with the Grand-duke with logical arguments, as if with magical incantations to charm the new planets out of the sky." Another opponent of Galileo, one Christmann, says, in a book he published, "We are not to think that Jupiter has four satellites given him by nature, in order, by revolving round him, to immortalize the Medici who first had notice of the observation. These are the *dreams of idle men*, who love ludicrous ideas better than our laborious and industrious correction of the heavens. Nature abhors so horrible a chaos, and to the truly wise such vanity is detestable." One Martin Horky, a would-be philosopher, declared to Kepler, "I will never concede his four new planets to that Italian from Padua, *though I should die for it*;" and he followed up this declaration by publishing a book against Galileo, in which he examines four principal questions respecting the alleged planets: 1. Whether they exist? 2. What they are? 3. What they are like? 4. Why they are? The first question is soon disposed of by declaring positively that he has examined the heavens with Galileo's own glass, and that no such thing as a satellite about Jupiter exists. To the second, he declares solemnly that he does not more surely know that he has a soul in his body than that reflected rays are the sole cause of Galileo's erroneous observations. In regard to the third question, he says that these planets are like the smallest fly compared to an elephant; and finally concludes, on the fourth, that the only use of them is to gratify Galileo's "thirst of gold," and to afford himself a subject of discussion. Kepler, in a letter to Galileo, when alluding to Horky, says, "He begged so hard to be forgiven, that I have taken him again into favour upon this preliminary condition, that I am to show him Jupiter's satellites, AND HE IS TO SEE THEM, and own that they are there."

The following is a specimen of the reasoning of certain pretended philosophers of that age against the discoveries of Galileo: Sizzi, a Florentine astronomer, reasons in this strain: "There are seven windows given to animals in the domicil of the head, through which the air is admitted to the rest of the tabernacle of the body, to enlighten, to warm, and to nourish it; two nostrils, two eyes, two ears, and a mouth; so in the heavens, or the great world, there are two favourable stars, two unpropitious, two luminaries, and Mercury alone undecided and indifferent. From which, and many other similar phenomena in nature, such as the seven metals, &c., we gather that the number of planets is *necessarily seven*. Moreover, the satellites are invisible to the naked eye, and therefore can exert no influence on the earth, and therefore would be useless, *and therefore do not exist*. Besides, as well the Jews as other ancient nations have adopted the division of the week into seven days, and have named them from the seven planets. Now, if we increase the number of the planets, this whole system falls to the ground." The opinions which then prevailed in regard to Galileo's observations on the moon were such as the following: Some thought that the dark shades on the moon's surface arose from the interposition of opaque bodies floating between her and the sun, which prevent his light from reaching those parts; others imagined that, on account of her vicinity to the earth, she was partly tainted with the imperfections of our terrestrial and elementary nature, and was not of that entirely pure and refined substance of which the more remote heavens consist; and a third party looked on her as a vast mirror, and maintained that the dark parts of her surface were the reflected images of our earthly forests and mountains.

Such learned nonsense is a disgrace to our species, and to the rational faculties with which man is endowed, and exhibits, in a most ludicrous manner, the imbecility and prejudice of those who made bold pretensions to erudition and philosophy. The statement of such facts, however, may be instructive, if they tend to guard us against those prejudices and preconceived opinions which prevent the mind from the cordial reception of truth, and from the admission of improvements in society which run counter to long-established customs. For the same principles and prejudices, though in a different form, still operate in

society, and retard the improvement of the social state, the march of science, and the progress of Christianity. How ridiculous is it for a man calling himself a philosopher to be afraid to look through a glass to an existing object in the heavens, lest it should endanger his previous opinions! And how foolish is it to resist any improvement or reformation in society because it does not exactly accord with existing opinions and with "the wisdom of our ancestors!"

It is not a little surprising that Galileo should have first hit on that construction of a telescope which goes by his name, and which was formed with a *concave* glass next the eye. This construction of a telescope is more difficult to be understood in theory than one which is composed solely of convex glasses; and its field of view is comparatively very small, so that it is almost useless when attempted to be made of a great length. In the present day, we cannot help wondering that Galileo and other astronomers should have made such discoveries as they did with such an instrument, the use of which must have required a great degree of patience and address. Galileo's best telescope, which he constructed "with great trouble and expense," magnified the diameters of objects only thirty-three times; but its length is not stated, which would depend upon the focal distance of the concave eyeglass. If the eyeglass was two inches focus, the length of the instrument would be five feet four inches; if it was only one inch, the length would be two feet eight inches, which is the least we can allow to it —the object-glass being thirty-three inches focus, and the eyeglass placed an inch within this focus. With this telescope Galileo discovered the satellites of Jupiter, the crescent of Venus, and the other celestial objects to which we have alluded. The telescopes made in Holland are supposed to have been constructed solely of *convex* glasses, on the principle of the astronomical telescope; and if so, Galileo's telescope was in reality a new invention.

Certain other claimants of the invention of the telescope have appeared, besides those already mentioned. Francis Fontana, in his "Celestial Observations," says that he was assured by a Mr. Hardy, advocate of the Parliament of Paris, a person of great learning and undoubted integrity, that, on the death of his father, there was found among his things an old tube by which distant objects were distinctly seen, and that it was of a date long prior to the telescope lately invented, and had been kept by him as a secret. Mr. Leonard Digges, a gentleman who lived near Bristol in the seventeenth century, and was possessed of great and various knowledge, positively asserts in his "*Stratoticos*," and in another work, that his father, a military gentleman, had an instrument which he used in the field, by which he could bring distant objects near, and could know a man at the distance of three miles. Mr. Thomas Digges, in the preface to his "Pantometria," published in 1591, declares, "My father, by his continual painful practices, assisted by demonstrations mathematical, was able, and sundry times hath, by proportional glasses, duly situate in convenient angles, not only discovered things far off, read letters, numbered pieces of money, with the very coin and superscription thereof, cast by some of his friends of purpose, upon downs in open fields, but also, seven miles off, declared what hath been done that instant in private places. He hath also, sundry times, by the sunbeams, fired powder and discharged ordnance half a mile and more distant, and many other matters far more strange and rare, of which there are yet living divers witnesses."

It is by no means unlikely that persons accustomed to reflection, and imbued with a certain degree of curiosity, when handling spectacle glasses, and amusing themselves with their magnifying powers and other properties, might sometimes hit upon the construction of a telescope, as it only requires two lenses of different focal distances to be held at a certain distance from each other, in order to show distant objects magnified. Nay, even one lens, of a long focal distance, is sufficient to constitute a telescope of a moderate magnifying power, as I shall show in the sequel. But such instruments, when they happen to be constructed accidentally, appear to have been kept as secrets, and confined to the cabinets of the curious, so that they never came into general use; and as their magnifying power would probably be comparatively small, the appearance of the heavenly bodies would not be much enlarged by such instruments, nor is it likely that they would be often directed to the heavens. On the whole, therefore, we may conclude that the period when instruments of this description came into general use, and were applied to useful purposes, was when Galileo constructed his first telescopes.

## CHAPTER II.

### *Of the Camera Obscura.*

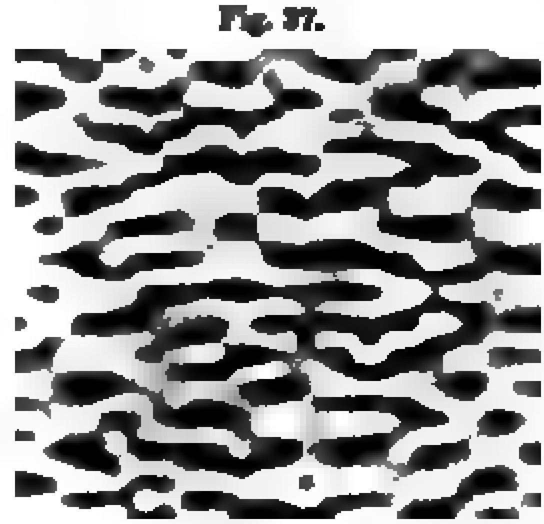
Before proceeding to a particular description of the different kinds of telescopes, I shall first give a brief description of the camera obscura, as the phenomena exhibited by this instrument tend to illustrate the principle of a refracting telescope.

The term *camera obscura* literally signifies a darkened vault or roof, and hence it came to denote a chamber, or box, or any other place made dark for the purpose of optical experiments. The camera obscura, though a simple, is yet a very curious and noble contrivance, as it naturally and clearly explains the manner in which vision is performed, and the principle of the telescope, and entertains the spectator with a most exquisite picture of surrounding objects, painted in the most accurate proportions and colours by the hand of nature. The manner of exhibiting the pictures of objects in a dark room is as follows: In one of the window-shutters of a room which commands a good prospect of objects not very distant, a circular hole should be cut of four or five inches diameter. In this hole an instrument should be placed called a *scioptric ball*, which has three parts, a frame, a ball, and a lens. The ball has a circular hole cut through the middle, in which the lens is fixed, and its use is to turn every way, so as to take in a view of objects on every side. The chamber should be made perfectly dark, and a white screen, or a large sheet of elephant paper, should be placed opposite to the lens, and in its focus, to receive the image. If, then, the objects without be strongly enlightened by the sun, there will be a beautiful living picture of the scene delineated on the white screen, where every object is beheld in its proportions, and with its colours even more vivid than life. Green objects appear in the picture more intensely green; and yellow, blue, red, or white flowers appear much more beautiful in the picture than in nature. If the lens be a good one, and the room perfectly dark, the perspective is seen in perfection. The lights and shadows are not only perfectly just, but also greatly heightened; and, what is peculiar to this delineation, and which no other picture or painting can exhibit, the *motions* of all the objects are exactly expressed in the picture; the boughs of the trees wave, the leaves quiver, the smoke ascends in a waving form, the people walk, the children at their sports leap and run, the horse and cart move along, the ships sail, the clouds soar and shift their aspects, and all as natural as in the real objects; the motions being somewhat quicker, as they are performed in a more contracted scene.

These are the *inimitable* perfections of a picture drawn by the rays of light as the only pencil in nature's hand, and which are finished in a moment; for no sensible interval elapses before the painting is completed, when the ground on which it is painted is prepared and adjusted. In comparison of such a picture, the finest productions of the most celebrated artists, the proportions of Raphael, the natural tints and colouring of Titian, and the shadowing of the Venetians, are but coarse and sorry daubing, when set in competition with what nature can exhibit by the rays of light passing through a single lens. The camera obscura is at the same time the painter's assistant and the painter's reproach. From the picture it forms he receives his best instructions, and he is shown what he should endeavour to attain; and hence, too, he learns the imperfections of his art, and what it is impossible for him to imitate. As a proof of this, the picture formed in the dark chamber will bear to be magnified to a great extent, without defacing its beauty or injuring the fineness of its parts; but the finest painted landscape, if viewed through a high magnifier, will appear only as a coarse daubing.

The following scheme will illustrate what

Fig. 37.



has been now stated respecting the dark chamber: *E F* represents a darkened room,

in the side of which, *I K*, is made the circular hole *V*, in which, on the inside, is fixed the scioptric ball. At some considerable distance from this hole is exhibited a landscape of houses, trees, and other objects. *A B C D*, which are opposite to the window. The rays which flow from the different objects which compose this landscape to the lens at *V*, and which pass through it, are converged to their respective foci on the opposite wall of the chamber, *H G*, or on a white movable screen placed in the focus of the lens, where they all combine to paint a lively and beautiful picture of the range of objects directly opposite, and on each side, so far as the lens can take in.

Though I have said that a scioptric ball and socket are expedient to be used in the above experiment, yet, where such an instrument is not at hand, the lens may be placed in a short tube, made of pasteboard or any other material, and fixed in the hole made in the window-shutter. The only imperfection attending this method is, that the lens can exhibit those objects only which lie directly opposite the window.

Some may be disposed to consider it as an imperfection in this picture, that all these objects appear in an *inverted* position; as they must necessarily do, according to what we formerly stated respecting the properties of convex lenses (p. 33.) There are, however, different modes of viewing the picture as if it were erect; for if we stand before the picture, and hold a common mirror against our breast at an acute angle with the picture, and look down upon it, we shall see all the images of the objects as if restored to their erect position; and by the reflection of the mirror, the picture will receive such a lustre as will make it still more delightful. Or, if a large concave mirror were placed before the picture at such a distance that its image may appear before the mirror, it will then appear erect and pendulous in the air in the front of the mirror. Or, if the image be received on a frame of paper, we may stand behind the frame, with our face towards the window, and look down upon the objects, when they will appear as if erect.

The experiment of the camera obscura may serve to explain and illustrate the nature of a common refracting telescope. Let us suppose that the lens in the window-shutter represents the object-glass of a refracting telescope. This glass forms an image in its focus, which is in every respect an exact picture or representation of the objects before it; and consequently the same idea is formed in the mind of the nature, form, magnitude, and colour of the object, whether the eye at the centre of the glass views the object itself, or the image formed in its focus; for, as formerly stated, the object and its image are both seen under the same angles by the eye placed at the centre of the lens. Without such an image as is formed in the camera obscura—depicted either in the tube of a telescope or in the eye itself—no telescope could possibly be formed. If we now suppose that, behind the image formed in the dark chamber, we apply a convex lens of a short focal distance to view that image, then the image will be seen distinctly, in the same manner as we view common objects, such as a leaf or a flower, with a magnifying glass; consequently, the object itself will be seen distinct and magnified; and as the same image is nearer to one lens than the other, it will subtend a larger angle at the nearest lens, and, of course, will appear larger than through the other, and consequently the object will be seen magnified in proportion. For example, let us suppose the lens in the camera obscura, or the object-lens of a telescope, to be five feet, or sixty inches focal distance: at this distance from the glass an image of the distant objects opposite to it will be formed. If, now, we place a small lens two inches focal distance beyond this point, or five feet two inches from the object-glass, the objects, when viewed through the small lens, will appear considerably magnified, and apparently much nearer than to the naked eye. The degree of magnifying power is in proportion to the focal distances of the two glasses; that is, in the present case, in the proportion of two inches, the focus of the small lens, to sixty inches, the focus of the object lens. Divide sixty by two, the quotient is thirty, which gives the magnifying power of such a telescope; that is, it represents objects thirty times nearer, or under an angle thirty times larger than to the naked eye. If the eyeglass, instead of being two inches, were only one and a half inch focus, the magnifying power would be in the proportion of one and a half to sixty, or forty times. If the eyeglass were three inches focus, the magnifying power would be twenty-times; and so on with regard to other proportions. In all cases, where a telescope is composed of only two convex lenses, the magnifying power is determined *by dividing the focal distance of the object-glass by the focal distance of the eyeglass*, and the quotient expresses the number of times the object is magnified in length and breadth. This and various other particulars will be more fully illustrated in the sequel.

In performing experiments with the camera obscura in a darkened chamber, it is requisite that the following particulars be attended to: 1. That the lens be well figured, and free from any veins or blemishes that might distort the picture. 2. That it be placed *directly*

*against* the object whose image we wish to see distinctly delineated. 3. The lens should be of a proper size, both as to its breadth and focal distance. It should not be less than three or four feet focal distance, otherwise the picture will be too small, and the parts of objects too minute to be distinctly perceived; nor should it exceed fifteen or eighteen feet, as in this case the picture will be faint, and of course not so pleasing. The best medium as to focal distance is from five to eight or ten feet. The aperture, too, or breadth of the glass, should not be too small, otherwise the image will be obscure, and the minute parts invisible for want of a sufficient quantity of light. A lens of six feet focal distance, for example, will require an aperture of at least two inches. Lenses of a shorter focal distance require less apertures, and those of a longer focal distance larger. But if the aperture be too large, the image will be confused and indistinct, by the admission of too much light. 4. We should never attempt to exhibit the images of objects, unless when the sun is shining and strongly illuminating the objects, except in the case of very near objects placed in a good light. As one of the greatest beauties in the phenomena of the dark chamber consists in the exquisite appearance and contrast of light and shadows, nothing of this kind can be perceived but from objects directly illuminated by the sun. 5. A south window should never be used in the forenoon, as the sun cannot then enlighten the north side of an object; and, besides, his rays would be apt to shine upon the lens, which would make the picture appear with a confused lustre. An east window is best in the afternoon, and a western in the morning; but a north window is in most cases to be preferred, especially in the forenoon, when the sun is shining with his greatest strength and splendour. In general, that window ought to be used which looks to the quarter opposite to that in which the sun is shining.

The picture should be received upon a very white surface, as the finest and whitest paper, or a painted cloth, bordered with black; as white bodies reflect most copiously the incumbent rays, while black surfaces absorb them. If the screen could be bent into the concave segment of a sphere, of which the focal distance of the double convex lens which is used is the radius, the parts of the picture adjacent to the extremities would appear most distinct. Sir D. Brewster informs us that, having tried a number of white substances of different degrees of smoothness, and several metallic surfaces on which to receive the image, he happened to receive the picture on the silvered back of a looking-glass, and was surprised at the brilliancy and distinctness with which external objects were represented. To remove the spherical protuberances of the tin foil, he ground the surface very carefully with a bed of hones which he had used for working the plane specula of Newtonian telescopes. By this operation, which may be performed without injuring the other side of the mirror, he obtained a surface finely adapted for the reception of images. The minute parts of the landscape were formed with so much precision, and the brilliancy of colouring was so uncommonly fine, as to equal, if not exceed, the images that are formed in the air by means of concave specula.

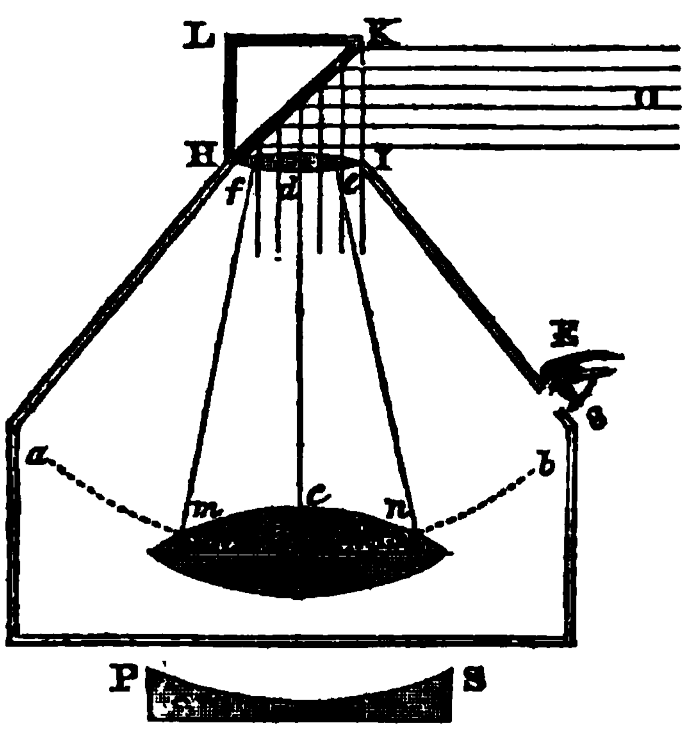
The following additional circumstances may be stated respecting the phenomena exhibited in the dark chamber: A more critical idea may be formed of any *movement* in the picture here presented than from observing the motion of the object itself. For instance, a man walking in a picture appears to have an undulating motion, or to rise up and down every step he takes, and the hands seem to move almost exactly like a pendulum; whereas scarcely any thing of this kind is observed in the man himself, as viewed by the naked eye. Again, if an object be placed just twice the focal distance from the lens without the room, the image will be formed at the same distance from the lens within the room, and, consequently, will be equal in magnitude to the object itself. The recognition of this principle may be of use to those concerned in drawing, and who may wish at any time to form a picture of the exact size of the object. If the object be placed further from the lens than twice its focal length, the image will be less than the object. If it be placed nearer, the image will be greater than the life. In regard to immovable objects, such as houses, gardens, trees, &c., we may form the images of so many different sizes by means of different lenses, the shorter focus making the lesser picture, and the longer focal distance the largest.

The experiments with the camera obscura may likewise serve to illustrate the nature of vision and the functions of the human eye. The frame or socket of the scioptric ball may represent the *orbit* of the natural eye. The ball, which turns every way, resembles the *globe* of the eye, movable in its orbit. The hole in the ball may represent the *pupil* of the eye; the convex lens corresponds to the *crystalline humour*, which is shaped like a lens, and contributes to form the images of objects on the inner part of the eye. The dark chamber itself is somewhat similar to the *internal part of the eye*, which is lined all around, and under the retina, with a membrane, over which is spread a mucus of a very black colour. The white wall or frame of

white paper to receive the picture of objects is a fair representation of the *retina* of the eye, on which all the images of external objects are depicted. Such are some of the general points of resemblance between the apparatus connected with the dark chamber and the organ of vision; but the human eye is an organ of such exquisite construction, and composed of such a number and variety of delicate parts, that it cannot be adequately represented by any artificial contrivance.

The darkened chamber is frequently exhibited in a manner somewhat different from what we have above described, as in the following scheme (fig. 38,) which is termed

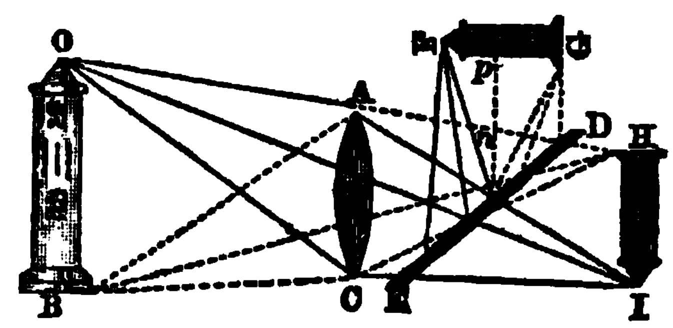
Fig. 38.




the *revolving camera obscura.* In this construction, *K H* represents a plane mirror or metallic reflector, placed at half a right angle to the convex lens *H I*, by which rays proceeding from objects situated in the direction *O* are reflected to the lens, which forms an image of the objects on a round white table at *T*, around which several spectators may stand and view the picture as delineated on a horizontal plane. The reflector, along with its case, is capable of being turned round by means of a simple apparatus connected with it, so as to take in, in succession, all the objects which compose the surrounding scene. But as the image here is received on a flat surface, the rays, *f m*, *e n*, will have to diverge further than the central rays, *d c*; and hence the representation of the object near the sides will be somewhat distorted; to remedy which, the image should be received on a concave surface, as *a b* or *P S*. This is the general plan of those camera obscuras, fitted up in large wooden tents, which are frequently exhibited in our large cities, and removed occasionally from one town to another. Were an instrument of this kind fitted up on a *small scale*, a hole might be made in one of the sides, as at *E*, where the eye could be applied to view the picture. The focal distances of the lenses used in large instruments of this kind are generally from eight to twelve feet, in which case they produce a telescopic effect upon distant objects, so as to make them appear nearer than when viewed with the naked eye.

The camera obscura is frequently constructed in a *portable form*, so as to be carried about for the purpose of delineating landscapes. The following is a brief description of the instrument in this form; *A C*

Fig. 39.




is a convex lens, placed near the end of a tube or drawer, which is movable in the side of a square box, within which is a plane mirror, *D E*, reclining backward in an angle of forty-five degrees from the perpendicular, *p n*. The pencils of rays flowing from the object *O B*, and passing through the convex lens, instead of proceeding forward and forming the image *H I*, are reflected upward by the mirror, and meet in points, as *F G*, at the same distance at which they would have met at *H* and *I*, if they had not been intercepted by the mirror. At *F G*, the image of the object *O B*, is received either on a piece of oiled paper, or more frequently on a plane *unpolished* glass, placed in the horizontal situation *F G*, which receives the images of all objects opposite to the lens, and on which, or on an oiled paper placed upon it, their outlines may be traced by a pencil. The movable tube on which the lens is fixed serves to adjust the focus for near and distant objects, till their images appear distinctly painted on the horizontal glass at *F G*. The following is the most common form of the box of this kind of camera obscura. *A* is the position of the lens, *B C* the position of the mirror, *D* the plane unpolished glass on which the images are depicted, *G H* a movable top or screen to prevent the light from injuring the picture, and *E F* the movable tube.

*The Daguerreotype.*—An important and somewhat surprising discovery has lately been made in relation to the picture formed by the camera obscura. It is found that the images formed by this instrument are capable of being indelibly fixed on certain surfaces previously prepared for the purpose, so that the

picture is rendered permanent. When a camera is presented to any object or landscape

Fig. 40.

strongly illuminated by the sun, and the prepared ground for receiving the image is adjusted, and a certain time allowed to elapse till the rays of light produce their due effect, in a few minutes, or even seconds, a picture of the objects opposite to the lens is indelibly impressed upon the prepared plate, in all the accurate proportions and perspective which distinguish the images formed in a dark chamber, which representations may be hung up in apartments, along with other paintings and engravings, and will likely retain their beauty and lustre for many years. These are pictures of nature's own workmanship, finished in an extremely short space of time, and with the most exquisite delicacy and accuracy. The effect is evidently owing to certain chemical properties in the rays of light, and opens a new field for experiment and investigation to the philosopher. The only defect in the picture is, that it is not coloured; but, in the progress of experiments, on this subject, it is not unlikely that even this object may be accomplished, in which case we should be able to obtain the most accurate landscapes and representations of all objects which can possibly be formed. This art or discovery goes by the name of the *Daguerreotype*, from M. Daguerre, a Frenchman, who is supposed to have been the first discoverer, and who received a large premium from the French government for disclosing the process, and making the discovery public. Several improvements and modifications, in reference to the preparation of the plates, have been made since the discovery was first announced, about the beginning of 1839; and the pictures formed on this principle are frequently distinguished by the name of *Photogenic* drawings, and are now exhibited at most of our public scientific institutions.

This new science or art has been distinguished by different names. It was first called *Photography*, from two Greek words, signifying *writing by light*; it was afterward called the art of *Photogenic Drawing*, or drawing produced by light. M. Daguerre gave it the name of *Heliography*, or *writing by the sun*; all which appellatives are derived from the Greek, and are expressive, in some degree, of the nature of the process. We shall, however, make use of the term Daguerreotype, derived from the name of the inventor.

As it does not fall within our plan to give any minute descriptions of the Daguerreotype process, we shall just give a few general hints in reference to it, referring those who wish for particular details to the separate treatises which have been published respecting it. The first thing necessary to be attended to in this art is the preparation of the plate on which the drawing is to be made. The plate consists of a thin leaf of copper, plated with silver, both metals together not being thicker than a card. The object of the copper is simply to support the silver, which must be the purest that can be procured. But, though the copper should be no thicker than to serve the purpose of support, it is necessary that it should be so thick as to prevent the plate from being warped, which would produce a distortion of the images traced upon it. This plate must be polished; and for this purpose the following articles are required; a vial of olive oil; some very fine cotton; pumice-powder ground, till it is almost impalpable, and tied up in a piece of fine muslin, thin enough to let the powder pass through without touching the plate when the bag is shaken; a little nitric acid, diluted with sixteen times, by measure, its own quantity of water; a frame of wire on which to place the plate when being heated; a spirit lamp to make the plate hot; a small box, with inclined sides within, and having a lid to shut it up close; and a square board large enough to hold the drawing, and having catches at the side to keep it steady.

To the above prerequisites, a good *camera obscura* is, of course, essentially necessary. This instrument should be large enough to admit the plate of the largest drawing intended to be taken. The lens which forms the image of the object should, if possible, be *achromatic*, and of a considerable diameter. In an excellent instrument of this description now before me, the lens is an achromatic about three inches diameter, but capable of being contracted to a smaller aperture. Its focal distance is about 17 inches; and the box, exclusive of the tube which contains the lens, is 15 inches long, 13½ inches broad, and 11 inches deep. It forms a beautiful and well-defined picture of every well enlightened object to which it is directed.

Before the plate is placed in the camera, there are certain operations to be performed. 1. The surface of the plate should be made perfectly smooth, or highly polished. For

this purpose it must be laid flat, with the silver side upward, upon several folds of paper for a bedding; and having been well polished in the usual way, the surface must be powdered equally and carefully with fine pumice inclosed in the muslin bag. Then taking a little cotton wool, dipped in olive oil, it must be rubbed over the plate with rounding strokes, and then crossing them by others which commence at right angles with the first. This process must be repeated frequently, changing the cotton, and renewing the pumice-powder every time. A small portion of cotton must now be moistened with the diluted nitric acid, and applied equally to the whole surface. The next thing to be done is to make the plate thoroughly and equally hot, by holding the plate with a pair of pincers by the corner over a charcoal fire, and when the plate is sufficiently hot, a white coating will be observed on the silver, which indicates that that part of the operation is finished. An even cold surface is next wanted, such as a metallic plate cooled almost to the freezing point by muriate of soda, and to this the heated plate must be suddenly transferred.

2. The next operation is to give the plate a coating of *iodine*. This is accomplished by fixing the plate upon a board, and then putting it into a box containing a little dish with iodine divided into small pieces, with its face downward, and supported with small brackets at the corners. In this position the plate must remain till it assume *a full gold colour*, through the condensation of the iodine on its surface, which process should be conducted in a darkened apartment. The requisite time for the condensation of the iodine varies from five minutes to half an hour. When this process is satisfactorily accomplished, the plate should be immediately fixed in a frame with catches and bands, and placed in the camera; and the transference from one receptacle to another should be made as quickly as possible, and with only so much light as will enable the operator to see what he is doing.

3. The next operation is to obtain the drawing. Having placed the camera in front of the scene to be represented, and the lens being adjusted to the proper focus, the ground glass of the camera is withdrawn, and the prepared plate is substituted for it, and the whole is left till the natural images are drawn by the natural light from the object. The time necessary to leave the plate for a complete delineation of the objects depends upon the intensity of the light. Objects in the shade will require more time for their delineation than those in the broad light. The full, clear light of the south of Europe, Spain, Italy, and particularly the more glowing brilliancy of tropical countries, will effect the object much more speedily than the duller luminosity of a northern clime. Some hours of the day are likewise more favourable than others. Daguerre states that "the most favourable is from 7 A.M. to 3 o'clock P.M., and that a drawing could be effected in Paris in three or four minutes in June and July, which would require five or six in May and August, and seven or eight in April and September." In the progress of this art, at the present time, portraits and other objects are frequently delineated in the course of a few seconds.

4. Immediately after removing the plate from the camera, it is next placed over the vapour of mercury, which is placed in a cup at the bottom of a box, and a spirit lamp applied to its bottom till the temperature rise to 140° of Fahrenheit. This process is intended to bring out the image, which is not visible when withdrawn from the camera; but in the course of a few minutes a faint tracery will begin to appear, and in a very short time the figure will be clearly developed.

5. The next operation is *to fix the impression*. In order to this, the coating on which the design was impressed must be removed, to preserve it from being decomposed by the rays of light. For this purpose, the plate is placed in a trough containing common water, plunging and withdrawing it immediately, and then plunging it into a solution of salt and water till the yellow coating has disappeared.

Such is a very brief sketch of the *photogenic* processes of Daguerre. Other substances, however, more easily prepared, have been recommended by Mr. Talbot, F.R.S., who appears, about the same time, to have invented a process somewhat similar to that of Daguerre. The following are his directions for the preparation of *photogenic paper:*

The paper is to be dipped into a solution of salt in water, in the proportion of half an ounce of salt to half a pint of water. Let the superfluous moisture drain off, and then laying the paper upon a clean cloth, *dab* it gently with a napkin, so as to prevent the salt collecting in one spot more than in another. The paper is then to be pinned down, by two of its corners on a drawing-board by means of common pins, and one side washed or wetted with the photogenic fluid, using the brush prepared for that purpose, and taking care to distribute it equally. Next, dry the paper as rapidly as you can at the fire, and it will be fit for use for most purposes. If, when the paper is exposed to the sun's rays, it should assume an irregular tint, a very thin extra wash of the fluid will render the colour uniform, and, at the same time, somewhat darker. Should it be required to make a more sensitive description of paper, after the first application of the fluid the solution of salt should be applied, and the

paper dried at the fire. Apply a second wash of the fluid, and dry it at the fire again: employ the salt a third time, dry it, and one application more of the fluid will, when dried, have made the paper extremely sensitive. When slips of such papers, differently prepared, are exposed to the action of daylight, those which are soonest affected by the light, by becoming dark, are the best prepared.

When photogenic drawings are finished in a perfect way, the designs then taken on the plate or paper are exceedingly beautiful and correct, and will bear to be inspected with a considerable magnifying power, so that the most minute portions of the objects delineated may be distinctly perceived. We have seen portraits finished in this way by a London artist with an accuracy which the best miniature painter could never attempt, every feature being so distinct as to bear being viewed with a deep magnifier. And in landscapes and buildings, such is the delicacy and accuracy of such representations, that the marks of the chisel and the crevices in the stones may frequently be seen by applying a magnifying lens to the picture; so that we may justly exclaim, in the words of the poet, "Who can paint like Nature!" That LIGHT —which is the first-born of Deity, which pervades all space, and illuminates all worlds— in the twinkling of an eye, and with an accuracy which no art can imitate, depicts every object in its exact form and proportions, superior to every thing that human genius can produce.

The photogenic art, in its progress, will doubtless be productive of many highly interesting and beneficial effects. It affords us the power of representing, by an accurate and rapid process, all the grand and beautiful objects connected with our globe, the landscapes peculiar to every country, the lofty ranges of mountains which distinguish Alpine regions, the noble edifices which art has reared, the monumental remains of antiquity, and every other object which it would be interesting for human beings to contemplate; so that, in the course of time, the general scenery of our world, in its prominent parts, might be exhibited to almost every eye. The commission of the French Chambers, when referring to this art, has the following remark: "To copy the millions upon millions of hieroglyphics which cover even the exterior of the great monuments of Thebes and Memphis, of Carnac, &c., would require scores of years and legions of designers. By the assistance of the Daguerreotype, a single man could finish that immense work." This instrument lays down objects which the visual organs of man would overlook, or might be unable to perceive, with the same minuteness and nicety that it delineates the most prominent features of a landscape. The time-stained excrescences on a tree, the blades of grass, the leaf of a rose, the neglected weed, the moss on the summit of a lofty tower, and similar objects, are traced with the same accuracy as the larger objects in the surrounding scene.

It is not improbable, likewise, that this art (still in its infancy,) when it approximates to perfection, may enable us to take representations of the sublime objects in the heavens. The sun affords sufficient light for this purpose; and there appears no insurmountable obstacle in taking, in this way, a highly-magnified picture of that luminary, which shall be capable of being again magnified by a powerful microscope. It is by no means improbable, from experiments that have hitherto been made, that we may obtain an accurate delineation of the lunar world from the moon herself. The plated disks prepared by Daguerre receive impressions from the action of the lunar rays to such an extent as permits the hope that photographic charts of the moon may soon be obtained; and, if so, they will excel in accuracy all the delineations of this orb that have hitherto been obtained; and if they should bear a microscopic power, objects may be perceived on the lunar surface which have hitherto been invisible. Nor is it impossible that the planets Venus, Mars, Jupiter, and Saturn may be delineated in this way, and objects discovered which cannot be descried by means of the telescope. It might, perhaps, be considered as beyond the bounds of probability to expect that even distant *nebulæ* might thus be fixed, and a delineation of their objects produced which shall be capable of being magnified by microscopes; but we ought to consider that the art is yet only in its infancy, that plates of a more delicate nature than those hitherto used may yet be prepared, and that other properties of light may yet be discovered which shall facilitate such designs. For we ought now to set no boundaries to the discoveries of science, and to the practical applications of scientific discovery which genius and art may accomplish.

In short, this invention leads to the conclusion that we have not yet discovered all the wonderful properties of that luminous agent which pervades the universe, and which unveils to us its beauties and sublimities; and that thousands of admirable objects and agencies may yet be disclosed to our view through the medium of light, as philosophical investigators advance in their researches and discoveries. In the present instance, as well as in many others, it evidently appears that the Creator intends, in the course of his providence, by means of scientific researches, gra-

dually to open to the view of the inhabitants of our world the wonders, the beauties, and the sublimities of his vast creation; to manifest his infinite wisdom and his superabundant goodness, and to raise our souls to the contemplation and the love of Him who is the original source of all that is glorious and beneficent in the scene of nature.

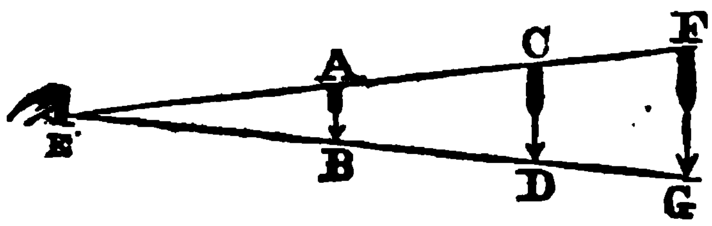
## CHAPTER III.

### *On the Optical Angle, and the Apparent Magnitude of Objects.*

In order to understand the principle on which telescopes represent distant objects as magnified, it may be expedient to explain what is meant by the angle of vision, and the apparent magnitudes under which different objects appear, and the same object, when placed at different distances.

The optical angle is the angle contained under two right lines drawn from the extreme points of an object to the eye. Thus *A E B* or *C E D* (fig. 40*) is the optical or visual

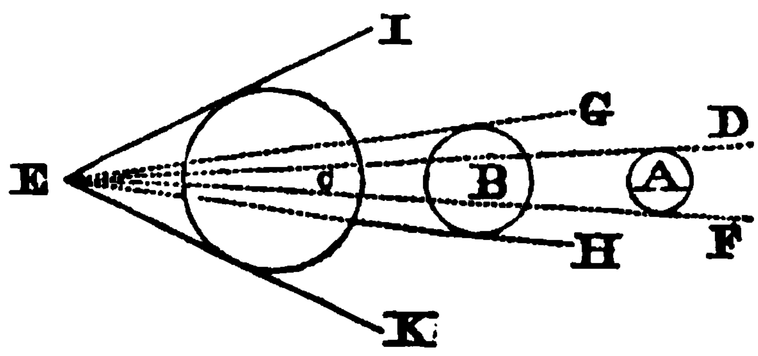
Fig. 40*




angle, or the angle under which the object *A B* or *C D* appears to the eye at *E*. These two objects, being at different distances, are seen under the same angle, although *C D* is evidently larger than *A B*. On the retina of the eye, their images are exactly of the same size, and so is the still larger object *F G*.

The *apparent magnitude* of objects denotes their magnitude as they appear to us, in contradistinction from their real or true magnitude, and it is measured by the visual angle; for, whatever objects, are seen under the same or equal angles *appear* equal, however different their real magnitudes. If a half crown or half dollar be placed at about 120 yards from the eye, it is just perceptible as a visible point, and its apparent magnitude, or the angle under which it is seen, is very small. At the distance of thirty or forty yards, its bulk appears sensibly increased, and we perceive it to be a round body; at the distance of six or eight yards we can see the king or queen's head engraved upon it; and at the distance of eight or ten inches from the eye it will appear so large that it will seem to cover a large building placed within the distance of a quarter of a mile; in other words, the apparent magnitude of the half crown, held at such a distance, will more than equal that of such a building in the picture on the retina, owing to the increase of the optical angle. If we suppose *A* (fig 41) to represent the apparent size of the half crown at

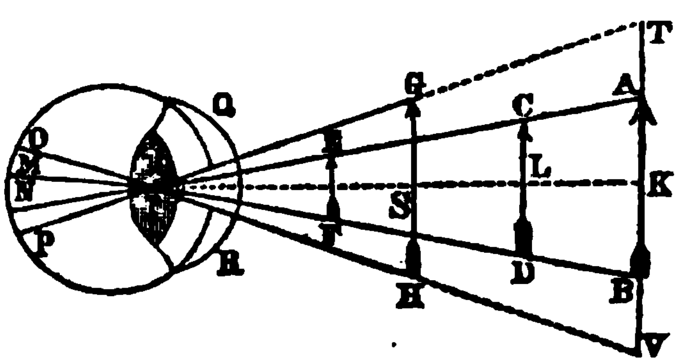
Fig. 41.




nine yards' distance, then we say it is seen under the small angle *F E D*. *B* will represent its apparent magnitude at 4½ yards distant under the angle *H E G*, and the circle *C*, its apparent magnitude at 3 yards distant, under the large angle *K E I*.

This may be otherwise illustrated by the following figure: Let *A B* (fig. 42) be an

Fig. 42.




object viewed directly by the eye *Q R*. From each extremity *A* and *B* draw the lines *A N*, *B M*, intersecting each other in the crystalline humour in *I*: then is *A I B* the optical angle which is the measure of the apparent magnitude or length of the object *A B*. From an inspection of this figure, it will evidently appear that the apparent magnitudes of objects will vary according to their distances. Thus *A B*, *C D*, *E F*, the real magnitudes of which are unequal, may be situated at such distances from the eye as to have their *apparent* magnitudes all equal, and occupying the same space on the retina, *M N*, as here represented. In like manner, objects of equal magnitude, placed at unequal distances, will appear unequal. The objects *A B* and *G H*, which are equal, being situated at different distances from

the eye, $G\ H$ will appear under the large angle $T\ I\ V$, or as large as an object $T\ V$, situated at the same place as the object $A\ B$, while $A\ B$ appears under the smaller angle $A\ I\ B$. Therefore the object $G\ H$ is *apparently* greater than the object $A\ B$, though it is only equal to it. Hence it appears that we have no certain standard of the *true magnitude* of objects by our visual perception abstractly considered, but only of the *proportions* of magnitude.

In reference to apparent magnitudes, we scarcely ever judge any object to be so great or so small as it appears to be, or that there is so great a disparity in the visible magnitude of two equal bodies at different distances from the eye. Thus, for example, suppose two men, each six feet three inches high, to stand directly before us, one at the distance of a pole, or 5½ yards, and the other at the distance of 100 poles, or 550 yards: we should observe a considerable difference in their apparent size, but we should scarcely suppose, at first sight, that the one nearest the eye appeared a hundred times greater than the other, or that, while the nearest one appeared six feet three inches high, the remote one appeared only about *three-fourths of an inch*. Yet such is in reality the case; and not only so, but the visible bulk or area of the one is to that of the other as the square of these numbers, namely, as 10,000 to 1; the man nearest us presenting to the eye a magnitude or surface ten thousand times greater than that of the other. Again, suppose two chairs standing in a large room, the one twenty-one feet distance from us, and the other three feet; the one nearest us will appear seven times larger, both in length and breadth, than the more distant one, and, consequently, its visible area forty-nine times greater. If I hold up my finger at nine inches distance from my eye, it seems to cover a large town a mile and a half in extent, situated at three miles distance; consequently, the apparent magnitude of my finger, at nine inches distance from the organ of vision, is greater than that of the large town at three miles distance, and forms a larger picture on the retina of the eye. When I stand at the distance of a foot from my window, and look through one of the panes to a village less than a quarter of a mile distant, I see, through that pane, nearly the whole extent of the village, comprehending two or three hundred houses; consequently, the apparent magnitude of the pane is equal to nearly the extent of the village, and all the buildings it contains do not appear larger than the pane of glass in the window, otherwise the houses and other objects which compose the village could not be seen through that single pane. For, if we suppose a line drawn from one end of the village, passing through the one side of the pane, and another line drawn from the other end, and passing through the other side of the pane to the eye, these lines would form the optical angle under which the pane of glass and the village appears. If the pane of glass be fourteen inches broad, and the length of the village 2640 yards, or half a mile, this last lineal extent is 6788 times greater than the other, and yet they have the same *apparent* magnitude in the case supposed.

Hence we may learn the absurdity and futility of attempting to describe the extent of spaces in the heavens, by saying that a certain phenomenon was two or three feet or yards distant from another, or that the tail of a comet appeared several yards in length. Such representations can convey no definite ideas in relation to such magnitudes, unless it be specified at what distance from the eye the foot or yard is supposed to be placed. If a rod, a yard in length, be held at nine inches from the eye, it will subtend an angle, or cover a space in the heavens, equal to more than one-fourth of the circumference of the sky, or about one hundred degrees. If it be eighteen inches from the eye, it will cover a space equal to fifty degrees; if at three feet twenty-five degrees, and so on in proportion to the distance from the eye; so that we can form no correct conceptions of apparent spaces or distances in the heavens, when we are merely told that two stars, for example, appear to be three yards distant from each other. The only definite measure we can use in such a case is that of degrees. The sun and moon are about half a degree in apparent diameter, and the distance between the extreme stars in *Orion's belt* three degrees, which measures, being made familiar to the eye, may be applied to other spaces of the heavens, and an approximate idea conveyed of the relative distances of objects in the sky.

From what has been stated above, it is evident that the magnitude of objects may be considered in different points of view. The true dimensions of an object, considered in itself, give what is called its *real* or *absolute magnitude*; and the opening of the visual angle determines the *apparent magnitude*. The real magnitude, therefore, is a constant quantity; but the apparent magnitude varies continually with the distance, real or imaginary; and, therefore, if we always judged of the dimensions of an object from its apparent magnitude, every thing around us would, in this respect, be undergoing very sensible variations, which might lead us into strange and serious mistakes. A fly, near enough to the eye, might appear under an angle as great as an elephant at the distance of twenty feet, and the one be mistaken for the other. A giant

eight feet high, seen at the distance of twenty-four feet, would not appear taller than a child two feet in height at the distance of six feet; for both would be seen nearly under the same angle. But our experience generally prevents us from being deceived by such illusions. By the help of touch, and by making allowance for the different distances at which we see particular objects, we learn to correct the ideas we might otherwise form from attending to the optical angle alone, especially in the case of objects that are near us. By the sense of touch we acquire an impression of the distance of an object; this impression combines itself with that of the apparent magnitude, so that the impression which represents to us the real magnitude is the product of these two elements. When the objects, however, are at a great distance, it is more difficult to form a correct estimate of their true magnitudes. The visual angles are so small that they prevent comparison; and the estimated bulks of the objects depend, in a great measure, upon the *apparent* magnitudes; and thus an object situated at a great distance appears to us much smaller than it is in reality. We also estimate objects to be nearer or further distant according as they are more or less clear, and our perception of them more or less distinct and well defined; and likewise when several objects intervene between us and the object we are particularly observing. We make a sort of addition of all the estimated distances of intermediate objects, in order to form a total distance of the remote object, which, in this case, appears to be further off than if the intervening space were unoccupied. It is generally estimated that no terrestrial object can be distinctly perceived if the visual angle it subtends be less than *one minute of a degree*, and that most objects become indistinct when the angle they subtend at the pupil of the eye is less than six minutes.

We have deemed it expedient to introduce the above remarks on the apparent magnitude of objects, because the principal use of a telescope is to increase the angle of vision, or to represent objects under a larger angle than that under which they appear to the naked eye, so as to render the view of distant objects more distinct, and to exhibit to the organ of vision those objects which would otherwise be invisible. A telescope may be said to enlarge an object just as many times as the angle under which the instrument represents it is greater than that under which it appears to the unassisted eye. Thus the moon appears to the naked eye under an angle of about half a degree; consequently, a telescope magnifies 60 times if it represents that orb under an angle of 30 degrees; and if it magnified 180 times, it would exhibit the moon under an angle of 90 degrees, which would make her appear to fill half of the visible heavens, or the space which intervenes from the horizon to the zenith.

## CHAPTER IV.

### *On the Different kinds of Refracting Telescopes.*

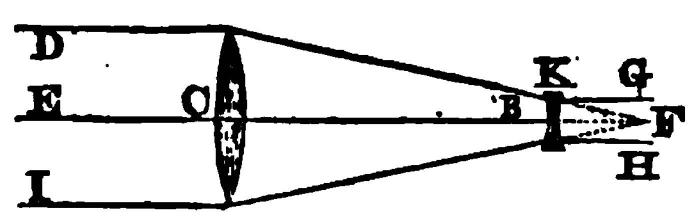
There are two kinds of telescopes, corresponding to two modes of vision, namely, those which perform their office by *refraction* through lenses, and those which magnify distant objects by *reflection* from mirrors. The telescope which is constructed with lenses produces its effects solely by refracted light, and is called a Dioptric, *or refracting telescope*. The other kind of telescope produces its effects partly by reflection, and partly by refraction, and is composed both of mirrors and lenses; but the mirrors form the principal part of the telescope, and therefore such instruments are denominated *reflecting telescopes*. In this chapter I shall describe the various kinds of *refracting* telescopes.

#### Section. I.

#### *The Galilean Telescope.*

This telescope is named after the celebrated Galileo, who first constructed, and probably *invented* it in the year 1609. It consists of only two glasses, a *convex* glass next the object, and a *concave* next the eye. The convex is called the *object-glass*, and the concave, to which the eye is applied, is called the *eye-glass*. Let $C$ (fig. 43) represent the convex

Fig. 43.




object-glass, presented to any object in the direction $D\ E\ I$, so that the rays fall parallel upon it; if these rays, after passing through it, were not intercepted by the concave lens $K$, they would pass on, and cross each other in the focus $F$, where an inverted image of the object would be formed. But the concave lens $K$, the virtual focus of which is at $F$,

being interposed, the rays are not suffered to converge to that point, but are made less convergent,* and enter the pupil almost parallel, as $G H$, and are converged by the humours of the eye to their proper foci on the retina. The object, through this telescope, is seen upright, or in its natural position, because the rays are not suffered to come to a focus, so as to form an inverted picture. The concave eyeglass is placed as far within the focus of the object-glass as is equal to its own virtual focus; and the magnifying power is as the focal length of the object-glass to that of the eyeglass, that is, as $C F$ to $B F$. Thus, suppose the focus of the object-glass to be ten inches, and the focus of the eyeglass to be one inch, the magnifying power will be ten times, which is always found by dividing the focal length of the object-glass by that of the eyeglass. The interval between the two glasses, in this case, will be nine inches, which is the length of the telescope, and the objects seen through it will appear under an angle ten times greater than they do to the naked eye. These propositions might be proved mathematically; but the process is somewhat tedious and intricate, and might not fully be understood by general readers. I shall therefore only mention some of the general properties of this telescope, which is now seldom used, except for the purpose of *opera-glasses*.

1. The focal distance of the object-glass must be greater than that of the eyeglass, otherwise it would not magnify an object; if the focal distance of the eyeglass were greater than that of the object-glass, it would diminish objects instead of magnifying them. 2. The visible area of the object is greater, the nearer the eye is to the glass; and it depends on the diameter of the pupil of the eye, and on the breadth of the object-glass; consequently, the field of view in this telescope is very small. 3. The distinctness of vision in this construction of a telescope exceeds that of almost any other. This arises from the rays of light proceeding from the object directly through the lenses, *without crossing* or intersecting each other; whereas, in the combination of convex lenses, they intersect one another to form an image in the focus of the object-glass, and this image is magnified by the eyeglass with all its imperfections and distortions. The thinness of the centre of the concave lens also contributes to distinctness. 4. Although the field of view in this telescope is very small, yet, where no other telescope can be procured, it might be made of such a length as to show the spots on the Sun, the crescent of Venus, the satellites of Jupiter, and the ring of Saturn; and, requiring only two glasses, it is the cheapest of all telescopes. It has been found that an object-lens five feet focal distance will bear a concave eyeglass of only one inch focal distance, and will consequently magnify the diameters of the planets sixty times, and their surfaces 3600 times, which is sufficient to show the phenomena now stated. And, although only a small portion of the sun and moon can be seen at once, yet Jupiter and all his satellites may sometimes be seen at one view; but there is some difficulty in finding objects with such telescopes. 5. Opera-glasses, which are always of this construction, have the object-lens generally about six inches focus and one inch diameter, with a concave eyeglass of about two inches focus. These glasses magnify about three times in diameter, have a pretty large field, and produce very distinct vision. When adjusted to the eye, they are about four inches in length. To the object-end of an opera-glass there is sometimes attached a plane mirror, placed at an angle of forty-five degrees, for the purpose of viewing objects on either side of us. By this means, in a theatre or assembly, we can take a view of any person without his having the least suspicion of it, as the glass is directed in quite a different direction. The instrument with this appendage is sometimes called a *Polemoscope*.

* It is one of the properties of concave lenses to render convergent rays less convergent, and when placed as here supposed, to render them parallel; and it is parallel rays that produce distinct vision.

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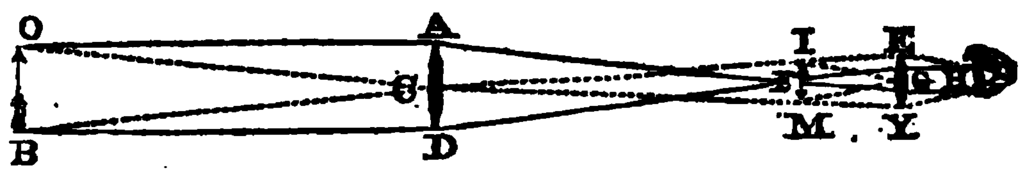
### Section II.

### *The Common Astronomical Refracting Telescope.*

The astronomical telescope is the most simple construction of a telescope, composed of convex lenses only, of which there are but two essentially necessary, though a third is sometimes added to the eyepiece for the purpose of enlarging the field of view. Its construction will be easily understood from a description of the following figure: Its two essential parts are an object-glass, $A D$, and an eyeglass $E Y$, so combined in a tube that the focus $F$ of the object-glass is exactly coincident with the focus of the eyeglass. Let $O B$ (fig. 44) represent a distant object, from which rays nearly parallel proceed to the object-lens $A D$. The rays passing through this lens will cross at $F$, and form an image of the object at $I M$. This image forms, as it were, an object to the eyeglass $E Y$, which is of a short focal distance, and the eye is thus enabled to contemplate the object as if it were brought much nearer than it is in reality; for

Fig. 44.




the rays, which, after crossing, proceed in a divergent state, fall upon the lens *E Y* as if they proceeded from a real object situated at *F*. All that is effected, therefore, by such a telescope is to form an image of a distant object by means of the object-lens, and then to give the eye such assistance as is necessary for viewing that image as near as possible, so that the angle it shall subtend at the eye shall be very large compared with the angle which the object itself would subtend in the same situation.

Here it may be expedient to explain, 1. How this arrangement of glasses shows distant objects distinctly; and 2. The reason why objects appear magnified when seen through it. As to the first particular, it may be proved as follows: The rays *O A* and *B D*, which are parallel before they fall upon the object-glass, are by this glass refracted and united at its focus. In order, then, to distinct vision, the eyeglass must re-establish the parallelism of the rays, which is effected by placing the eyeglass so that its focus may be at *F*, and, consequently, the rays will proceed from it parallel to each other, and fall upon the eye in that direction; for distinct vision is produced by *parallel* rays. 2. The reason why the object appears magnified will appear, if we consider that, if the eye viewed the object from the centre of the object-glass, it would see it under the angle *O C B*; let *O C* and *B C* then be produced to the focus of the glass, they will then limit the image, *I M*, formed in the focus. If, then, two parallel rays are supposed to proceed to the eyeglass *E Y*, they will be converged to its focus *H*, and the eye will see the image under the angle *E H Y*. The apparent magnitude of the object, therefore, as seen by the naked eye, is to the magnitude of the image as seen through the telescope, as *O C B* to *E H Y*, or as the distance *C F* to the distance *F G*; in other words, *as the focal length of the object-glass to that of the eyeglass.*

It is obvious from the figure, that, through this telescope, all objects will appear *inverted;* since the object *O B* is depicted by the object-glass in an inverted position at *I M*, and in this position is viewed by the eyeglass *E Y*; and, therefore, this kind of telescope is not well adapted for viewing terrestrial objects, since it exhibits the tops of trees, houses, and other objects as undermost, and the heads of people as pointing downward. But this circumstance is of no consequence with respect to the heavenly bodies, since they are round, and it can make little difference to an observer which side of a globular body appears uppermost or undermost. All astronomical refracting telescopes invert objects; but they are preferred to any other telescopes, because they have few glasses, and, consequently, more light. This telescope, however, can be transformed into a common day telescope for land objects by the addition of two other eyeglasses, as we shall afterward explain; but in this case a quantity of light is lost by refraction at each lens, for there is scarcely any transparent substance that transmits all the rays of light that fall upon it.

The *magnifying power* of this telescope is found *by dividing the focal distance of the object-glass by the focal distance of the eyeglass;* the quotient gives the magnifying power, or the number of times that the object seen through the telescope appears larger or nearer than to the naked eye. Thus, for example, if the focal distance of the object-glass be 28 inches, and the focal distance of the eyeglass 1 inch, the magnifying power will be 28 times. If we would enlarge the telescope, and select an object-glass 10 feet, or 120 inches focus, an eyeglass of 2 inches focal length might be applied, and then the diameter of objects would be magnified 60 times, and their surfaces 3600 times. If we would use an object-glass of 100 feet, it would be necessary to select an eyeglass about 6 inches focus, and the magnifying power would be 200 times, equal to 1200 inches divided by 6. Since, then, the power of magnifying depends on the proportion of the focal length of the object and eyeglasses, and this proportion may be varied to any degree, it may seem strange to some that a short telescope of this kind will not answer that purpose as well as a long one. For instance, it may be asked why an object-glass of 10 feet focus may not be made to magnify as much as one of 100 feet focal length, by using an eyeglass of half an inch focus, in which case the magnifying power would be 240 times? But it is to be considered that, if the power of magnifying be increased while the length of the telescope remains the same, it is necessary to diminish the focal length of the eyeglass in the same proportion, and this cannot be done, on account of the great distortion and colouring which would then appear in the image, arising both from the deep convexity of the lens and the different refrangibility of the rays of light. It is found that the length of common refracting telescopes must be increased in proportion to the square of the increase of their magnifying

power; so that, in order to magnify twice as much as before with the same light and distinctness, the telescope must be lengthened four times; to magnify 3 times as much, 9 times; and to magnify 4 times as much, 16 times; that is—suppose a telescope of 3 feet to magnify 33 times—in order to procure a power four times as great, or 132 times, we must extend the telescope to the length of 48 feet, or 16 times the length of the other. Much, likewise, depends upon the breadth or aperture of the object-glass. If it be too small, there will not be sufficient light to illuminate the object; and if it be too large, the redundance of light will produce confusion in the image.

The following table, constructed originally by Huygens, and which I have recalculated and corrected, shows the linear aperture, the focal distance of the eyeglass, and the magnifying power of astronomical telescopes of different lengths, which may serve as a guide to those who wish to construct telescopes of this description:

| Focal distance of the object-glass. | Linear aperture of the object-glass. | Focal distance of the eyeglass. | Magnifying power. |
|---|---|---|---|
| Feet. | Inc. Dec. | Inc. Dec. | |
| 1 | 0. 545 | 0. 60 | 20 |
| 2 | 0. 76 | 0. 84 | 28.5 |
| 3 | 0. 94 | 1. 04 | 34.6 |
| 4 | 1. 08 | 1. 18 | 40 |
| 5 | 1. 21 | 1. 33 | 45 |
| 6 | 1. 32 | 1. 45 | 50 |
| 7 | 1. 43 | 1. 58 | 53 |
| 8 | 1. 53 | 1. 69 | 56.8 |
| 9 | 1. 62 | 1. 78 | 60.6 |
| 10 | 1. 71 | 1. 88 | 63.8 |
| 15 | 2. 10 | 2. 30 | 78 |
| 20 | 2. 43 | 2. 68 | 89.5 |
| 30 | 3. 00 | 3. 28 | 109 |
| 40 | 3. 43 | 3. 76 | 127 |
| 50 | 3. 84 | 4. 20 | 142 |
| 60 | 4. 20 | 4. 60 | 156 |
| 70 | 4. 55 | 5. 00 | 168 |
| 80 | 4. 83 | 5. 35 | 179 |
| 90 | 5. 15 | 5. 65 | 190 |
| 100 | 5. 40 | 5. 95 | 200 |
| 120 | 5. 90 | 6. 52 | 220 |

In the above table the first column expresses the focal length of the object-glass in feet, the second column the diameter of the aperture* of the object-glass, the third column the focal distance of the eyeglass, and the fourth the magnifying power, which is found by reducing the feet in the first column to inches, and dividing by the numbers in the third column. From this table it appears that, in order to obtain a magnifying power of 168 times by this kind of telescope, it is requisite to have an object-glass of 70 feet focal distance, and an eyeglass five inches focus, and that the aperture of the object-glass ought not to be more than about 4½ inches diameter. To obtain a power of 220 times requires a length of 120 feet.

The following is a summary view of the properties of this telescope: 1. The object is always inverted. 2. The magnifying power is always in the proportion of the focal distance of the object-glass to the eyeglass. 3. As the rays emerging from the eyeglass should be rendered parallel for every eye, there is a small sliding tube next the eye, which should be pushed out or in till the object appears distinct. When objects are pretty near, this tube requires to be pulled out a little. These circumstances require to be attended to in all telescopes. 4. The apparent magnitude of an object is the same wherever the eye be placed, but the visible area, or field of view, is the greatest when the eye is nearly at the focal distance of the eyeglass. 5. The visual angle depends on the breadth of the eyeglass, for it is equal to the angle which the eyeglass subtends at the object-glass; but the breadth of the eyeglass cannot be increased beyond a certain limit without producing colouring and distortion.

If the general principles on which this telescope is constructed be thoroughly understood, it will be quite easy for the reader to understand the construction of all the other kinds of telescopes, whether refracting or reflecting. A small astronomical telescope can be constructed in a few moments, provided one has at hand the following lenses: 1. A common reading-glass, eight or ten inches focal distance; 2. A common magnifying lens, such as watchmakers or botanists use, of about 1½ or 2 inches focus. Hold the reading-glass—suppose of ten inches focus—in the left hand opposite any object, and the magnifying lens of two inches focus in the right hand near the

* The word *aperture*, as applied to object-glasses, signifies the opening to let in the light, or that part of the object-glass which is left uncovered. An object-glass may be 3 inches in diameter, but if one inch of this diameter be covered, its aperture is said to be only 2 inches.

eye, at twelve inches distance from the other in a direct line, and a telescope is formed which magnifies five times. I have frequently used this plan, when travelling, when no other telescope was at hand.

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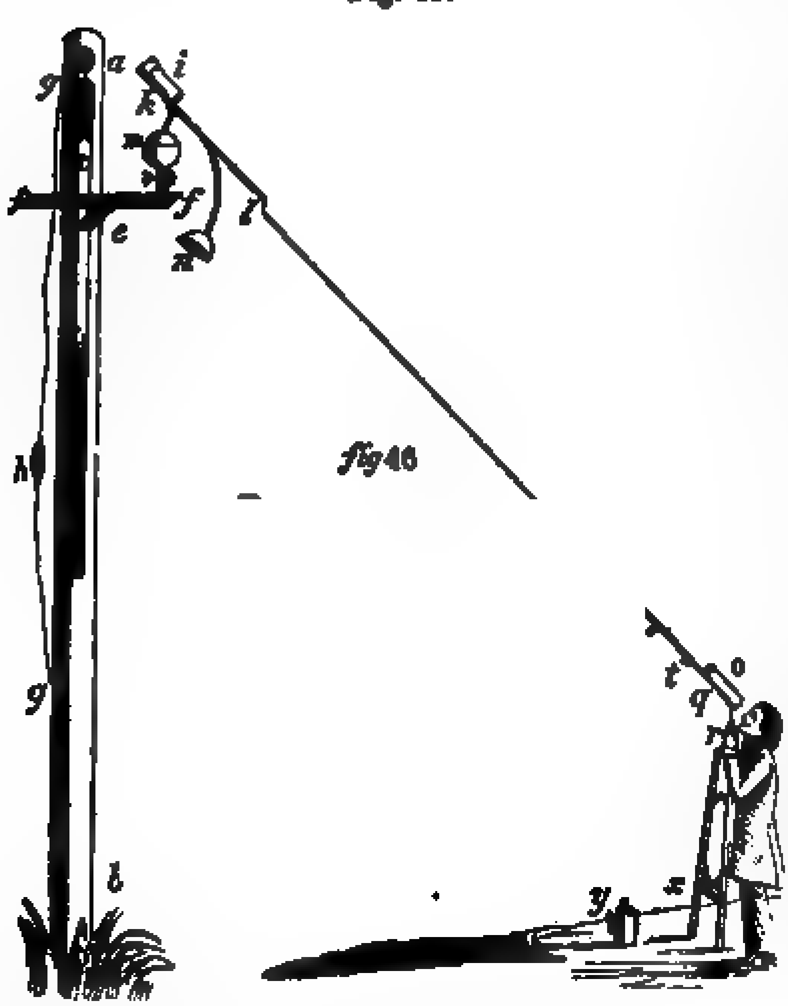
### Section III.

#### *The Aerial Telescope.*

The aerial is a refracting telescope of the kind we have now described, intended to be used without a tube in a dark night; for the use of a tube is not only to direct the glasses, but to make the place dark where the images are formed. It appears, from the preceding table, that we cannot obtain a high magnifying power with the common astronomical telescope without making it of an extreme length, in which case the glasses are not manageable in tubes—which are either too slight and apt to bend, or too heavy and unwieldy if made of wood, iron, or other strong materials. The astronomers of the seventeenth century, feeling some inconveniences in making celestial observations with long tubes, contrived a method of using the glasses without tubes. Hartsocker, an eminent optician, contrived to fix them at the top of a tree, a high wall, or the roof of a house; but the celebrated Huygens, who was not only an astronomer, but also an excellent mechanic, made considerable improvements in the method of using an object-glass without a tube. He placed it at the top of a very long pole, having previously inclosed it in a short tube, which was made to turn in all directions by means of a ball and socket. The axis of this tube he could command with a fine silken string, so as to bring it into a line with the axis of another short tube which he held in his hand, and which contained the eyeglass. The following is a more particular description of one of these telescopes: On the top of a long pole or mast, *a b* (*fig.* 45,) is fixed a board movable up and down in the channel *c d*; *e* is a perpendicular arm fixed to it, and *f f* is a transverse board that supports the object-glass inclosed in the tube *i*, which is raised or lowered by means of the silk cord *r l*; *g g* is an endless rope with a weight *h*, by which the apparatus of the object-glass is counterpoised; *k l* is a stick fastened to the tube *i*; *m* the ball and socket, by means of which the object-glass is movable every way; and, to keep it steady, there is a weight, *n*, suspended by a wire; *l* is a short wire to which the thread *r l* is tied; *o* is the tube which holds the eyeglass; *q* the stick fixed to this tube, *s* a leaden bullet, and *t* a spool to wind the thread on; *u* is pins for the thread to pass through; *x* the rest for the observer to lean upon, and *y* the lantern. Fig. 46 is an apparatus contrived by M. de la Hire for managing the object-glass, but which it would be too tedious particularly to describe. To keep off the dew from the object-glass, it was sometimes included in a pasteboard tube, made of spongy paper, to absorb the humidity of the air. And, to find an object more readily, a broad annulus of white pasteboard was put over the tube that carried the eyeglass, upon which the image of the object being painted, an assistant who perceived it might direct the tube of the eyeglass into its place.

Fig. 45.




Such was the construction of the telescopes with which Hevelius, Huygens, Cassini, and other eminent astronomers of the seventeenth century made their principal discoveries. With such telescopes Huygens discovered the fourth satellite of Saturn, and determined that this planet was

surrounded with a ring; and with the same kind of instrument Cassini detected the first, second, third, and fifth satellites of Saturn, and made his other discoveries. When the night was very dark, they were obliged to make the object-glass visible by means of a lantern so constructed as to throw the rays of light up to it in a parallel direction. In making such observations they must have taken incredible pains, endured much cold and fatigue, and subjected themselves to very great labour and expense—which almost makes us wonder at the discoveries they were instrumental in bringing to light—and should make modern philosophers sensible of the obligations they are under to such men as Newton and Dollond, through whose inventions such unwieldy instruments are no longer necessary. Telescopes of the description now stated were made of all sizes, from 30 to above 120 feet in length. Divini at Rome, and Campani at Bologna, were famed as makers of the object-glasses of the long focal distance to which we have alluded, who sold them for a great price, and took every method to keep the art of making them a secret. It was with telescopes made by Campani that Cassini made his discoveries. They were made by the express order of Louis XIV., and were of 86, 100, and 136 Paris feet in focal length. M. Auzout made one object-glass of 600 feet focus; but he was never able to manage it so as to make any practical observations with it. Hartsocker is said to have made some of a still greater focal length. The famous aerial telescope of Huygens was 123 feet in focal length, with six inches of aperture. At his death he bequeathed it to the Royal Society of London, in whose possession it still remains. It required a pole of more than a hundred feet high on which to place the object-glass for general observations. It was with this glass that Dr. Derham made the observations to which he alludes in his preface to his "Astro-Theology." When this glass was in the possession of Mr. Cavendish, it was compared with one of Mr. Dollond's forty-six inch treble object-glass achromatics, and the gentlemen who were present at the trial, said that "the Dwarf was fairly a match for the Giant." It magnified 218 times, and the trouble of managing it was said to be extremely tiresome and laborious.

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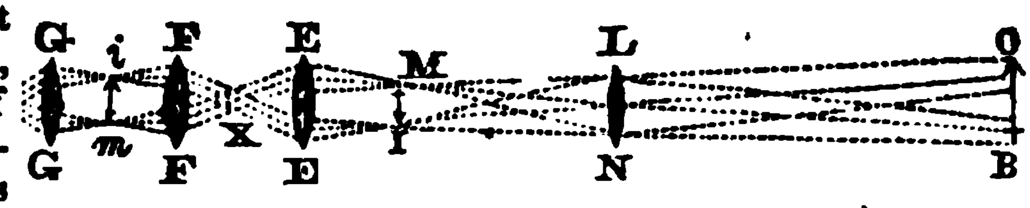
## Section IV.

### *The common Refracting Telescope, for Terrestrial Objects.*

This telescope is constructed on the same

Fig 47.




principle as the astronomical telescope already described, with the addition of two or three glasses. In fig. 47, $O$ $B$ represents a distant object, $L$ $N$ the object-glass, which forms the image $I$ $M$ in its focus, which is, of course, in an inverted position, and, if the eye were applied to the lens $E$ $E$, the object would appear exactly as through the astronomical telescope, every object being apparently turned upside down. To remedy this inconvenience, there are added two other glasses, $F$ $F$ and $G$ $G$, by which a second image is formed from the first, in the same position as the object. In order to effect this, the first of these two glasses, namely, $F$ $F$, is placed at twice its focal distance from the former glass, $E$ $E$, and the other lens, $G$ $G$, next the eye, is placed at the same distance from $F$ $F$; for all the three glasses are supposed to be of the same focal distance. Now the lens $F$ $F$, being placed at twice the focal distance for parallel rays from $E$ $E$, receives the pencils of parallel rays after they have crossed each other at $X$, and forms an image at $i$ $m$ similar to that at $I$ $M$, and equal to it, but contrary in position, and consequently erect; which last image is viewed by the lens $G$ $G$, in the same manner as the first image, $I$ $M$, would be viewed by the lens $E$ $E$. In this case the image $I$ $M$ is considered as an object to the lens $F$ $F$, of which it forms a picture in its focus, in a reverse position from that of the first image, and, of course, in the same position as the object.

The magnifying power of this telescope is determined precisely in the same way as that of the astronomical telescope. Suppose the object-glass to be thirty inches focal distance, and each of the eye-glasses $1\frac{1}{2}$ inch focal distance, the magnifying power is in the proportion of 30 to $1\frac{1}{2}$, or 20 times, and the instrument is, of course, considerably longer than an astronomical telescope of the same power. The distance, in this case, between the object-glass and the first eyeglass, $E$ $E$, is $31\frac{1}{2}$ inches; the distance between $E$ $E$ and the second glass, $F$ $F$, is 3 inches, and the distance between $F$ $F$ and the glass $G$ $G$, next the eye, 3 inches; in all, $37\frac{1}{2}$ inches, the whole length of the telescope. Although it is usual to make use of three eyeglasses in this telescope, yet two will cause the object to appear erect, and of the same magnitude. For, suppose the middle lens, $F$ $F$, taken away, if the first lens, $E$ $E$, be placed at $X$, which is double its focal distance from the

image, $I\ M$, it will, at the same distance, $X$ m, on the other side, form a secondary image, $i\ m$, equal to the primary image $I\ M$, and also in a contrary position. But such a combination of eyeglasses produces a great degree of colouring in the image, and therefore is seldom used. Even the combination now described, consisting of three lenses of equal focal distances, is now almost obsolete, and has given place to a much better arrangement, consisting of *four* glasses of different focal distances, which shall be afterward described.

The following figures, 48, 49, 50, represent the manner in which the rays of light are refracted through the glasses of the telescopes we have now described. Fig. 48 represents the rays of light as they pass from the object to the eye in the Galilean telescope. After passing in a parallel direction to the object-glass, they are refracted by that glass, and undergo a slight convergence in passing towards the concave eyeglass, where they enter the eye in a parallel direction, but no image is formed previous to their entering the eye till they arrive at the retina. Fig. 49 repre-

Fig. 48. Fig. 49. Fig. 50.

sents the rays as they pass through the glasses of the astronomical telescope. The rays, after entering the object-glass, proceed in a converging direction till they arrive at its focus about $A$, where an image of the object is formed; they then proceed diverging to the eyeglass, where they are rendered parallel, and enter the eye in that direction. Fig. 50 represents the rays as they converge and diverge in passing through the four glasses of the common day-telescope described above. After passing through the object-glass, they converge towards $B$, where the first image is formed. They then diverge towards the first eyeglass, where they are rendered parallel, and, passing through the second eyeglass, they again converge and form a second image at $C$, from which point they again diverge, and, passing through the first eyeglass, enter the eye in a parallel direction. If the glasses of these telescopes were fixed on long pieces of wood, at their proper distances from each other, and placed in a darkened room, when the sun is shining, the beam of the sun's light would pass through them in the same manner as here represented.

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## Section V.

### *Telescope formed by a Single Lens.*

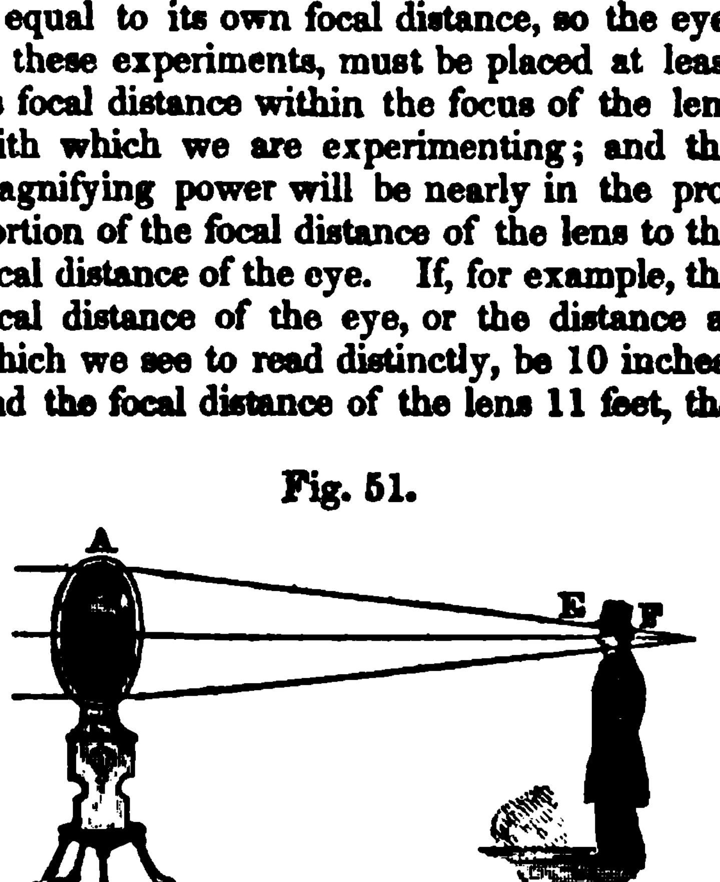
This is a species of telescope altogether unnoticed by optical writers, so far as I know; nor has the property of a single lens in magnifying distant objects been generally adverted to or recognized. It may not, therefore, be inexpedient to state a few experiments which I have made in relation to this point. When we hold a spectacle-glass of a pretty long focal distance—say from 20 to 24 inches—close to the eye, and direct it to distant objects, they do not appear sensibly magnified. But if we hold the glass about 12 or 16 inches from our eye, we shall perceive a sensible degree of magnifying power, as if distant objects were seen at less than half the distance at which they are placed. This property of a spectacle-glass I happened to notice when a boy, and on different occasions since that period have made several experiments on the subject, some of which I shall here relate.

With the object-glass of a common refracting telescope, 4½ feet focal distance, and 2¾ inches diameter, I looked at distant objects—my eye being at about 3½ feet from the lens, or about 10 or 12 inches within its focus—and it produced nearly the same effect as a telescope which magnifies the diameters of objects 5 or 6 times. With another lens, 11 feet focal distance and 4 inches diameter, standing from it at the distance of about ten feet, I obtained a magnifying power of about 12 or 14 times, which enabled me to read the letters on the signposts of a village half a mile distant. Having some time ago procured a very

large lens, 26 feet focal distance and 11½ inches diameter, I have tried with it various experiments of this kind upon different objects. Standing at the distance of about 25 feet from it, I can see distant objects through it magnified about 26 times in diameter, and consequently 676 times in surface, and remarkably clear and distinct, so that I can distinguish the hour and minute hands of a public clock in a village two miles distant. This single lens, therefore, answers the purpose of an ordinary telescope with a power of 26 times. In making such experiments, our eye must always be *within* the focus of the lens, at least 8 or 10 inches. The object will, indeed, be seen at any distance from the glass within this limit, but the magnifying power is diminished in proportion as we approach nearer to the glass. Different eyes, too, will require to place themselves at different distances, so as to obtain the greatest degree of magnifying power with distinctness, according as individuals are long or short-sighted.

This kind of telescope stands in no need of a tube, but only of a small pedestal on which it may be placed on a table, nearly at the height of the eye, and that it be capable of a motion in a perpendicular or parallel direction, to bring it in a line with the eye and the object. The principle on which the magnifying power in this case is produced, is materially the same as that on which the Galilean telescope depends. The eye of the observer serves instead of the concave lens in that instrument; and as the concave lens is placed as much within the focus of the object-glass as is equal to its own focal distance, so the eye, in these experiments, must be placed at least its focal distance within the focus of the lens with which we are experimenting; and the magnifying power will be nearly in the proportion of the focal distance of the lens to the focal distance of the eye. If, for example, the focal distance of the eye, or the distance at which we see to read distinctly, be 10 inches, and the focal distance of the lens 11 feet, the

Fig. 51.




magnifying power will be as 11 feet, or 132 inches to 10, that is, about 13 times. Let $A$ (fig. 51) represent the lens placed on a pedestal; the rays of light passing through this lens from distant objects will converge towards a focus at $F$. If a person then place his eye at $E$, a certain distance within the focal point, he will see distant objects magnified nearly in the proportion of the focal distance of the lens to that of the eye; and when the lens is very broad—such as the 26 feet lens mentioned above—two or three persons may look through it at once, though they will not all see the same object. I have alluded above to a lens made by M. Azout of 600 feet focal distance. Were it possible to use such a lens for distant objects, it might represent them as magnified 5 or 600 times, without the application of any eyeglass. In this way the aerial telescope of Huygens would magnify objects above 100 times, which is about half the magnifying power it produced with its eyepiece. Suppose Azout's lens had been fitted up as a telescope, it would not have magnified above 480 times, as it would have required an eyeglass of 14 or 15 inches focal distance, whereas, without an eyeglass, it would have magnified objects considerably above 500 times. It is not unlikely that the species of telescope to which I have now adverted constituted one of those instruments for magnifying distant objects which were said to have been in the possession of certain persons long before their invention in Holland, and by Galileo in Italy, to which I have referred in p. 69. Were this kind of telescope to be applied to the celestial bodies, it would require to be elevated upon a pole in the manner represented in fig. 45, p. 83.

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## Section VI.

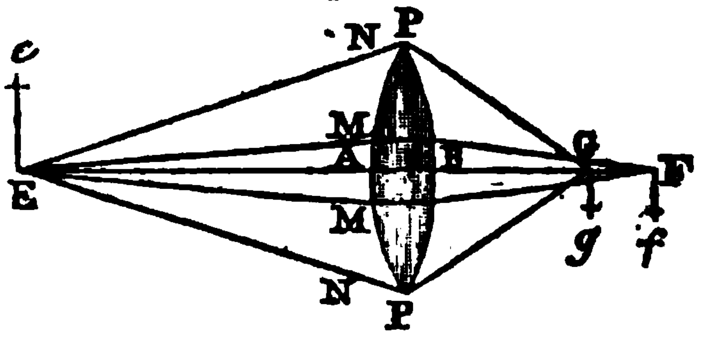
### *The Achromatic Telescope.*

This telescope constitutes the most important and useful improvement ever made upon telescopic instruments, and it is probable it will, ere long, supersede the use of all other telescopes. Its importance and utility will at once appear when we consider that a good achromatic telescope of only 4 or 5 feet in length will bear a magnifying power as great as that of a common astronomical telescope 100 feet long, and even with a greater degree of distinctness, so that they are now come into general use both for terrestrial and celestial observations. There are, indeed, certain obstructions which prevent their being made of a very large size; but from the improvement in the manufacture of achromatic glass which is now going forward, it is to be hoped that the difficulties which have hitherto impeded the progress of opticians will soon be removed. In order to understand the nature of this te e-

so, it will be necessary to advert a little to the *imperfections* connected with the common refracting telescopes.

The first imperfection to which I allude is this, that *spherical surfaces do not refract the rays of light accurately to a point;* and hence the image formed by a single convex lens is not perfectly accurate and distinct. The rays which pass near the extremities of such a lens meet in foci nearer to the lens than those which pass nearly through the centre, which may be illustrated by the following figure: Let *P P* (fig. 52) be a convex lens, and *E e*

Fig. 52.




an object, the point *E* of which corresponds with the axis, and sends forth the rays *E M*, *E N*, *E A*, &c., all of which reach the surface of the glass, but in different parts. It is manifest that the ray *E A*, which passes through the middle of the glass, suffers no refraction. The rays *E M*, *E M*, likewise, which pass through near to *E A*, will be converged to a focus at *F*, which we generally consider as the focus of the lens. But the rays *E N*, *E N*, which are nearer to the edge of the glass, will be differently refracted, and will meet about *G*, nearer to the lens, where they will form another image *G g*. Hence it is evident that the first image, *F f*, is formed only by the union of those rays which pass very near the centre of the lens; but as the rays of light proceeding from every point of an object are very numerous, there is a succession of images formed, according to the parts of the lens where they penetrate, which necessarily produces indistinctness and confusion. This is the imperfection which is distinguished by the name of *spherical aberration*, or the error arising from the spherical form of lenses.

The second and most important imperfection of single lenses, when used for the object-glasses of telescopes, is, that the rays of compounded light being differently refrangible, come to their respective foci at different distances from the glass; the more refrangible rays, as the *violet*, converging sooner than those which are less refrangible, as the *red*. I have had occasion to illustrate this circumstance, when treating on the colours produced by the prism, see p. 51, and figures 32 and 33,) and it is confirmed by the experiment of a paper painted red, throwing its image, by means of a lens, at a greater distance than another paper painted blue. From such facts and experiments, it appears that the image of a white object consists of an indefinite number of coloured images, the violet being nearest, and the red furthest from the lens, and the images of intermediate colours at intermediate distances. The aggregate, or image itself, must therefore be in some degree confused; and this confusion being much increased by the magnifying power, it is found necessary to use an eyeglass of a certain limited convexity to a given object-glass. Thus, an object-glass of 34 inches focal length will bear an eyeglass of only one inch focus, and will magnify the diameters of objects 34 times; one of 50 feet focal distance will require an eyeglass of 4½ inches focus, and will magnify only 142 times; whereas, could we apply to it an eyeglass of only one inch focus, as in the former case, it would magnify no less than 600 times. And were we to construct an object-glass of 100 feet focal length, we should require to apply an eyeglass not less than six inches focus, which would produce a power of about 200 times; so that there is no possibility of producing a great power by single lenses without extending the telescope to an immoderate length.

Sir Isaac Newton, after having made his discoveries respecting the colours of light, considered the circumstance we have now stated as an insuperable barrier to the improvement of refracting telescopes, and therefore turned his attention to the improvement of telescopes by *reflection*. In the telescopes which he constructed and partly invented, the images of objects are formed by reflection from speculums or mirrors; and being free from the irregular convergency of the various coloured rays of light, will admit of a much larger aperture and the application of a much greater degree of magnifying power. The reflector which Newton constructed was only six inches long, but it was capable of bearing a power equal to that of a six feet refractor. It was a long time, however, after the invention of these telescopes, before they were made of a size fitted for making celestial observations. After reflecting telescopes had been some time in use, Dollond made his famous discovery of the principle which led him to the construction of the *achromatic* telescope. This invention consists of a compound object-glass formed of two different kinds of glass, by which both the spherical aberration and the errors arising from the different refrangibility of the rays of light are in a great measure corrected. For the explanation of the nature of this compound object-glass and the effects it produces, it may be expedient to offer the following remarks respecting the dispersion of light and its refraction by different substances.

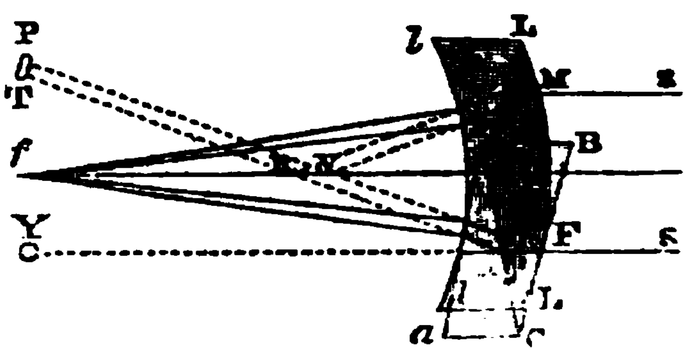
The *dispersion* of light is estimated by the

variable angle formed by the red and violet rays which bound the solar spectrum, or, rather, it is the excess of the refraction of the most refrangible ray above that of the least refrangible ray. The dispersion is not proportional to the refraction, that is, the substances which have an equal mean refraction do not *disperse* light in the same ratio. For example, if we make a prism with plates of glass, and fill it with oil of cassia, and adjust its refracting angle, *A C B* (fig. 31, p. 51,) so that the middle of the spectrum which it forms falls exactly at the same place where the green rays of a spectrum formed by a glass prism would fall, then we shall find that the spectrum formed by the *oil of cassia* prism will be two or three times *longer* than that of the *glass* prism. The oil of cassia, therefore, is said to *disperse* the rays of light more than the glass, that is, to separate the extreme red and violet rays at *O* and *P* more than the mean ray at *green*, and to have a greater *dispersive power*. Sir I. Newton appears to have made use of prisms composed of different substances, yet, strange to tell, he never observed that they formed spectrums whose lengths were different when the refraction of the green ray was the same, but thought that the dispersion was proportional to the refraction. This error continued to be overlooked by philosophers for a considerable time, and was the cause of retarding the invention of the achromatic telescope for more than 50 years.

Dollond was among the first who detected this error. By his experiments it appears that the different kinds of glass differ extremely with respect to the divergency of colours produced by equal refractions. He found that two prisms, one of white flint glass, whose refracting angle was about 25 degrees, and another of crown glass, whose refracting angle was about 29 degrees, refracted the beam of light nearly alike, but that the divergency of colour in the white flint was considerably more than in the crown glass; so that when they were applied together, to refract contrary ways, and a beam of light transmitted through them, though the emergent continued parallel to the incident part, it was, notwithstanding, separated into component colours. From this he inferred that, in order to render the emergent beam white, it is necessary that the refracting angle of the prism of crown glass should be *increased*, and by repeated experiments he discovered the exact quantity. By these means he obtained a theory in which refraction was performed without any separation or divergency of colour, and thus the way was prepared for applying the principle he had ascertained to the construction of the object-glasses of refracting telescopes. For the edges of a convex and concave lens, when placed in contact with each other, may be considered as two prisms which refract contrary ways; and if the excess of refraction in the one be such as precisely to destroy the divergency of colour in the other, a colourless image will be formed. Thus, if two lenses are made of the same focal length, the one of flint glass and the other of crown, the length or diameter of the coloured image in the first will be to that produced by the crown glass as three to two nearly. Now if we make the focal lengths of the lenses in this proportion, that is, as three to two, the coloured spectrum produced by each will be equal. But if the flint lens be concave, and the crown convex, when placed in contact they will mutually correct each other, and a pencil of white light refracted by the compound lens will remain colourless.

The following figure may perhaps illustrate what has been now stated. Let *L L* (fig. 53) represent a convex lens of *crown glass*,

Fig. 53.



and *l l* a concave lens of *flint glass*. A ray of the sun, *S*, falls at *F* on the convex lens, which will refract it exactly as the prism *A B C*, whose faces touch the two surfaces of the lens at the points where the ray enters and quits it. The solar ray, *S F*, thus refracted by the lens *L L*, or prism *A B C*, would have formed a spectrum, *P T*, on the wall, had there been no other lens, the violet ray, *F*, crossing the axis of the lens at *V*, and going to the upper end, *P*, of the spectrum; and the red ray, *F R*, going to the lower end, *T*. But as the flint glass lens *l l*, or the prism *A a C*, which receives the rays *F V*, *F R*, at the same points, is interposed, these rays will be united at *f*, and form a small circle of white light; the ray *S F* of the sun being now refracted without colour from its primitive direction *S F Y* into the new direction *F f*. In like manner, the corresponding ray *S M* will be refracted to *f*, and a white and colourless image of the sun will be there formed by the two lenses. In this combination of lenses, it is obvious that the spherical aberration of the flint lens corrects to a considerable degree that of the crown glass, and by a proper adjustment of the radii of the surfaces, it may be almost wholly removed. This

error is still more completely corrected in the *triple* achromatic object-glass, which consists of three lenses—a concave flint lens placed between convexes of crown glass. Fig. 54 shows the *double* achromatic lens, and fig. 55 the *triple* object-glass, as they are fitted up in

Fig. 54. Fig. 55.

their cells, and placed at the object-end of the telescope. In consequence of their producing a focal image free of colour, they will bear a much larger aperture and a much greater magnifying power than common refracting telescopes of the same length. While a common telescope whose object-glass is $3\frac{1}{2}$ feet focal distance will bear an aperture of scarcely one inch, the $3\frac{1}{2}$ feet achromatic will bear an aperture of $3\frac{1}{4}$ inches, and consequently transmits $10\frac{1}{2}$ times the quantity of light. While the one can bear a magnifying power of only about 36 times, the other will bear a magnifying power for celestial objects of more than 200 times.

The theory of the achromatic telescope is somewhat complicated and abstruse, and would require a more lengthened investigation than my limits will permit. But what has been already stated may serve to give the reader a general idea of the *principle* on which it is constructed, which is all I intended. The term *achromatic*, by which such instruments are now distinguished, was first given to them by Dr. Bevis. It is compounded of two Greek words which signify "free of colour." And were it not that even philosophers are not altogether free of that pedantry which induces us to select Greek words which are unintelligible to the mass of mankind, they might have been contented with selecting the plain English word *colourless*, which is as significant and expressive as the Greek word *achromatic*. The *crown glass*, of which the convex lenses of this telescope are made, is the same as good common window glass; and the *flint glass* is that species of glass of which wine-glasses, tumblers, decanters, and similar articles are formed, and is sometimes distinguished by the name of crystal glass. Some opticians have occasionally formed the concave lens of an achromatic object-glass from the bottom of a broken tumbler.

This telescope was invented and constructed by Mr. John Dollond about the year 1758. When he began his researches into this subject, he was a silk weaver in Spitalfields, London. The attempt of the celebrated Euler to form a colourless telescope, by including water between two meniscus glasses, attracted his attention, and in the year 1753 he addressed a letter to Mr. Short, the optician, which was published in the Philosophical Transactions of London, "concerning a mistake in Euler's theorem for correcting the aberrations in the object-glasses of refracting telescopes." After a great variety of experiments on the refractive and dispersive powers of different substances, he at last constructed a telescope in which an exact balance of the opposite dispersive powers of the crown and flint lenses made the colours disappear, while the predominating refraction of the crown lens disposed the achromatic rays to meet at a distant focus. In constructing such object-glasses, however, he had several difficulties to encounter. In the first place, the focal distance as well as the particular surfaces must be very nicely proportioned to the densities or refractive powers of the glasses, which are very apt to vary in the same sort of glass made at different times. In the next place, the centres of the two glasses must be placed truly in the common axis of the telescope, otherwise the desired effect will be in a great measure destroyed. To these difficulties is to be added, that there are four surfaces (even in double achromatic object-glasses) to be wrought perfectly spherical; and every person practised in optical operations will allow that there must be the greatest accuracy throughout the whole work. But these and other difficulties were at length overcome by the judgment and perseverance of this ingenious artist.

It appears, however, that Dollond was not the only person who had the merit of making this discovery—a private gentleman, Mr. Chest, of Chest Hall, a considerable number of years before, having made a similar discovery, and applied it to the same purpose. This fact was ascertained in the course of a process raised against Dollond, at the instance of Watkins, optician at Charing Cross, when applying for a patent. But as the other gentleman had kept his invention a secret, and Dollond had brought it forth for the benefit of the public, the decision was given in his favour. There was no evidence that Dollond borrowed the idea from his competitor, and both were, to a certain extent, entitled to the merits of the invention.

One of the greatest obstructions to the construction of large achromatic telescopes is the difficulty of procuring large disks of flint glass of a uniform refractive density, of good colour, and free from veins. It is said that, fortunately for Mr. Dollond, this kind of glass was procurable when he began to make achromatic telescopes, though the attempts of ingenious chemists have since been exerted to make it without much success. It is also said that the glass employed by Dollond in the fabrication of his best telescopes was of the same melting, or made at the same time, and that, excepting this particular treasure, casually obtained, good dense glass for achromatic purposes was always as difficult to be procured as it is now. The dispersion of the flint glass, too, is so variable, that, in forming an achromatic lens, trials on each specimen require to be made before the absolute proportional dispersion of the substances can be ascertained. It is owing in a great measure, to these circumstances that a large and good achromatic telescope cannot be procured unless at a very high price. Mr. Tulley, of Islington—who has been long distinguished as a maker of excellent achromatic instruments—showed me, about six years ago, a rude piece of flint glass about five inches diameter, intended for the concave lens of an achromatic object-glass, for which he paid eight guineas. This was before the piece of glass was either figured or polished, and, consequently, he had still to perform the delicate operation of figuring, polishing, and adjusting this concave to the convex lenses with which it was to be combined; and, during the process, some veins or irregularities might be detected in the flint glass which did not then appear. Some years before, he procured a disk of glass from the Continent, about seven or eight inches diameter, for which he paid about thirty guineas, with which an excellent telescope, twelve feet focal length, was constructed for the Astronomical Society of London. It is obvious, therefore, that large achromatic telescopes must be charged at a pretty high price.

In order to stimulate ingenious chemists and opticians to make experiments on this subject, the Board of Longitude, more than half a century ago, offered a considerable reward for bringing the art of making good flint glass for optical purposes to the requisite perfection. But considerable difficulties arise in attempting improvements of this kind, as the experiments must all be tried on a very large scale, and are necessarily attended with a heavy expense; and, although government has been extremely liberal in voting money for warlike purposes, and in bestowing pensions on those who stood in no need of them, it has thrown an obstruction in the way of such experiments, by the heavy duty of excise, which is rigorously exacted, whether the glass be manufactured into saleable articles or not, and has thus been instrumental in retarding the progress of improvement and discovery. It would appear that experiments of this kind have been attended with more success in France, Germany, and other places on the Continent than in Britain, as several very large achromatic telescopes have been constructed in those countries by means of flint glass, which was cast for the purpose in different manufactories, and to which British artists have been considerably indebted, as the London opticians frequently purchase their largest disks of flint glass from Parisian agents. Guinaud, a Continental experimenter, and who was originally a cabinetmaker, appears to have had his labours in this department of art crowned with great success. Many years were employed in his experiments, and he too frequently, notwithstanding all his attention, discovered his metal to be vitiated by striæ, specks, or grains, with cometic tails. He constructed a furnace capable of melting two *cwt.* of glass in one mass, which he sawed vertically, and polished one of the sections, in order to observe what had taken place during the fusion. From time to time, as he obtained blocks including portions of good glass, his practice was to separate them by sawing the blocks into horizontal sections, or perpendicular to their axes. A fortunate accident conducted him to a better process. While his men were one day carrying a block of this glass on a handbarrow to a sawmill which he had erected at the Fall of the Doubs, the mass slipped from its bearers, and rolling to the bottom of a steep and rocky declivity, was broken to pieces. Guinaud having selected those fragments which appeared perfectly homogeneous, softened them in circular moulds in such a manner, that, on cooling, he obtained disks that were afterwards fit for working. To this method he adhered, and contrived a way for clearing his glass while cooling, so that the fractures should follow the most faulty parts. When flaws occurred in the large masses, they were removed by cleaving the pieces with wedges; then smelting them again in moulds, which gave them the form of disks. The Astronomical Society of London have made trial of disks made by Guinaud, and have found them entirely homogeneous and free from fault. Of this ingenious artist's flint glass some of the largest achromatic telescopes on the Continent have been constructed. But it is more than twenty years since this experimenter took his flight from this terrestrial scene, and it is uncertain whether his process be still carried on with equal success.

*Notices of some large Achromatic Telescopes on the Continent and in Great Britain.*

1. *The Dorpat Telescope.*—This is one of the largest and most expensive refracting telescopes ever constructed. It was made by the celebrated Fraunhofer, of Munich, for the observatory of the Imperial University of Dorpat, and was received into the observatory by Professor Struve, in the year 1825. The aperture of the object-glass of this telescope is 9½ English inches, and its solar focal length about 14 feet, the main tube being 13 French feet, exclusive of the tube which holds the eyepieces. The smallest of the four magnifying powers it possesses is 175, and the largest 700, which, in favourable weather, is said to present the object with the utmost precision. "This instrument," says Struve, "was sold to us by Privy-counsellor Von Utzchneider, the chief of the optical establishment at Munich, for 10,500 florins (about £950 sterling,) a price which only covers the expenses which the establishment incurred in making it." The framework of the stand of this telescope is of oak, inlaid with pieces of mahogany in an ornamental manner, and the tube is of deal veneered with mahogany and highly polished. The whole weight of the telescope and its counterpoises is supported at one point, at the common centre of gravity of all its parts; and though these weigh 3000 Russian pounds, yet we are told that this enormous telescope may be turned in every direction towards the heavens with more ease and certainty than any other hitherto in use. When the object end of the telescope is elevated to the zenith, it is sixteen feet four inches, Paris measure, above the floor, and its eye end in this position is two feet nine inches high. This instrument is mounted on an equatorial stand, and clockwork is applied to the equatorial axis, which gives it a smooth and regular sidereal motion, which it is said, keeps a star in the exact centre of the field of view, and produces the appearance of a state of rest in the starry regions, which motion can be made solar, or even lunar, by a little change given to the place of a pointer that is placed as an index on the dial plate. Professor Struve considers the optical powers of this telescope superior to those of Schroeter's twenty-five feet reflector, from having observed $\sigma$ Orionis with fifteen companions, though Schroeter observed only twelve that he could count with certainty. Nay, he seems disposed to place it in competition with the late Sir W. Herschel's forty-feet reflector. The *finder* of this telescope has a focal distance of 30 French inches, and 2-42 aperture.

2. *Sir James South's Telescope.*—About the year 1829, Sir J. South, President of the London Astronomical Society, procured of M. Cauchoix, of Paris, an achromatic object-glass of 11 2-10 inches clear aperture, and of 19 feet focal length. The flint glass employed in its construction was the manufacture of the late Guinaud le Père, and was found to be absolutely perfect. The first observation was made with this telescope while on a temporary stand, on Feb. 13, 1830, when Sir J. Herschel discovered with it a *sixth* star in the trapezium in the nebula of Orion, whose brightness was about one third of that of the fifth star discovered by Struve, which is as distinctly seen as the companion to Polaris is in a five feet achromatic. Sir James gives the following notices of the performance of this instrument on the morning of May 14, 1830. "At half past two placed the 20 feet achromatic on the Georgium Sidus, saw it with a power of 346, a beautiful planetary disk; not the slightest suspicion of any ring, either perpendicular or horizontal; but the planet three hours east of the meridian, and the moon within three degrees of the planet. At a quarter before three, viewed *Jupiter* with 252 and 346, literally covered with belts, and the diameters of his satellites might have been as easily measured as himself. One came from behind the body, and the contrast of the colour with that of the planet's limb was striking. At three o'clock, viewed *Mars*. The contrast of light in the vicinity of the poles very decided. Several spots on his body well and strongly marked; that about the south pole seems to overtake the body of the planet, and gives an appearance not unlike that afforded by the new moon, familiarly known as 'the old moon in the moon's arms.'" *Saturn* has been repeatedly seen with powers from 130 to 928, under circumstances the most favourable; but not any thing anomalous about the planet or its ring could even be suspected. This telescope is erected on an equatorial stand, at Sir J. South's observatory, Kensington.

3. *Captain Smyth's Telescope in his private observatory at Bedford.*—This achromatic telescope is 8½ feet focal length, with a clear aperture of 5 9-10 inches, worked by the late Mr. Tulley, senior, from a disk purchased by Sir James South at Paris. It is considered by Captain Smyth to be the finest specimen of that eminent optician's skill, and, it is said, will bear with distinctness a magnifying power of 1200. Its distinctness has been proved by the clear vision it gives of the obscure nebulæ, and of the companions of Polaris, Rigel, $\alpha$ Lyræ, and the most minute double stars—the lunar mountains, cavities, and shadows under all powers—the lucid polar regions of Mars—the sharpness of the double ring of Saturn—the gibbous aspect of Venus—the shadows of

Jupiter's satellites across his body, and the splendid contrast of colours in $\alpha$ Hercules, $\gamma$ Andromedæ, and other superb double stars.

*Other large Achromatics.*—Besides the above, the following, belonging to public observatories and private individuals, may be mentioned. In the Royal Observatory at Greenwich there is an achromatic of 10 feet focal distance, having a double object-glass 5 inches diameter, which was made by Mr. Peter Dollond, and the only one of that size he ever constructed. There is also a 46 inch achromatic, with a triple object-glass 3¾ inches aperture, which is said to be the most perfect instrument of the kind ever produced. It was the favourite instrument of Dr. Maskelyne, late astronomer royal, who had a small room fitted up in the observatory for this telescope. The observatory some years ago erected near Cambridge is, perhaps, the most splendid structure of the kind in Great Britain. It is furnished with several very large achromatic telescopes on equatorial machinery; but the achromatic telescope lately presented to it by the Duke of Northumberland is undoubtedly the largest instrument of this description which is to be found in this country. The object-glass is said to be 25 feet focal distance, and of a corresponding diameter; but as there was no access to this instrument at the time I visited the observatory, nearly six years ago, I am unable to give a particular description of it. In the Royal Observatory at Paris, which I visited in 1837, I noticed, among other instruments, two very large achromatic telescopes, which, measuring them rudely by the eye, I estimated to be from 15 to 18 feet long, and the aperture at the object end from 12 to 15 inches diameter. They were the largest achromatics I had previously seen; but I could find no person in the observatory at that time who could give me any information as to their history, or to their exact dimensions or powers of magnifying.*

The Rev. Dr. Pearson, Treasurer to the Astronomical Society of London, is in possession of the telescope formerly alluded to, made by Mr. Tulley, of twelve feet focal distance and seven inches aperture, which is said to be a very fine one. The small star which accompanies the pole-star, with a power of 100, appears through this telescope as distinct and steady as one of Jupiter's satellites. With a single lens of 6 inches focus, which produced a power of 24 times, according to the testimony of an observer who noticed it, the small star appeared as it does in an achromatic of 3 inches aperture, which shows the great effect of illuminating power in such instruments. Mr. Lawson, a diligent astronomical observer in Hereford, possesses a most beautiful achromatic telescope of about 7 inches aperture and 12 feet focal distance, which was made by one of the Dollonds, who considered it as his *chef d'œuvre.* It is said to bear powers as high as 1100 or 1400, and has been fitted up with mechanism, devised by Mr. Lawson himself, so as to be perfectly easy and manageable to the observer, and which displays this gentleman's inventive talent. In several of his observations with this instrument, he is said to have had a view of some of the more minute subdivisions of the ring of Saturn. A very exellent achromatic telescope was fitted up some years ago by my worthy friend William Bridges, Esq., Blackheath. Its object-glass is 5½ inches diameter, and about 5¼ feet focal length. It is erected upon equatorial machinery, and placed in a circular observatory which moves round with a slight touch of the hand. The object-glass of this instrument cost about 200 guineas; the equatorial machinery on which it is mounted cost 150 guineas; and the circular observatory in which it is placed about 100 guineas, in all 450 guineas. Its powers vary from 50 to 300 times.†

*Achromatic Telescopes of a moderate size.*

Such telescopes as I have alluded to above are among the largest which have yet been made on the achromatic principle; they are, of course, comparatively rare, and can be afforded only at a very high price. Few of the *object-glasses* in the telescopes to which I have referred would be valued at less than 200 guineas, independently of the tubes, eyepieces, and other apparatus with which they are fitted up. It is so difficult to procure large disks of flint glass for optical purposes, to produce the requisite curves of the different lenses, and to combine them together with that extreme accuracy which is requisite, that, when a good compound lens of this description is found perfectly achromatic, the optician must necessarily set a high value upon it, since it may happen that he may have finished half a dozen before he has got one that is nearly perfect. The more common sizes of achromatic telescopes for astronomical purposes, which are regularly sold by the London opticians, are the following:

1. *The 2½ feet Achromatic.*—This telescope has an object-glass 30 inches in focal length, and 2 inches clear aperture. It is

* An achromatic telescope is said to be in possession of Mr. Cooper, M.P. for Sligo, which is 26 feet long, and the diameter of the object-glass 14 inches.

† This telescope, which was made by Dollond with a power of 210 times, gives a beautiful view of the belts of Jupiter, and the double ring of Saturn, and with a power of 50 the stars in the milky way and some of the nebulæ appear very numerous and brilliant. Its owner is a gentleman who unites science with Christianity.

generally furnished with two eyepieces, one for terrestrial objects, magnifying about 30 or 35 times, and one for celestial objects, with a power of 70 or 75 times. It might be furnished with an additional astronomical eyepiece, if the object-glass be a good one, so as to produce a power of 90 or 95 times. With such a telescope, the belts and satellites of Jupiter, the phases of Venus, and the ring of Saturn may be perceived, but not to so much advantage as with larger telescopes. It is generally fitted up either with a mahogany or a brass tube, and is placed upon a tripod brass stand, with a universal joint which produces a horizontal and vertical motion. It is packed, along with the eyepieces and whatever else belongs to it, in a neat mahogany box. Its price varies according as it is furnished with an elevating rack or other apparatus.

The following are the prices of this instrument, as marked in the catalogue of Mr. Tulley, Terrett's Court, Islington, London.

| | £ | s. | d. |
|---|---|---|---|
| 2½ feet telescopes, brass mounted on plain pillar and claw stand, with 1 eyepiece for astronomical purposes and 1 for land objects, to vary the magnifying power, packed in a mahogany box . . . . | 10 | 10 | 0 |
| Ditto, ditto, brass mounted on pillar and claw stand, with elevating rack, 1 eyepiece for astronomical purposes, and 1 for land objects, to vary the magnifying power, packed in a mahogany box | 12 | 12 | 0 |

The following prices of the same kind of telescope are from the catalogue of Messrs. W. and S. Jones, 30 Lower Holborn, London.

| | £ | s. | d. |
|---|---|---|---|
| The improved 2½ feet achromatic refractor, on a brass stand, mahogany tube, with three eyepieces, two magnifying about 40 and 50 times for terrestrial objects, and the other about 75 times for astronomical purposes, in a mahogany case | 10 | 10 | 0 |
| Ditto, ditto, the tube all brass, with three eyepieces . . . | 11 | 11 | 0 |
| Ditto, ditto, with vertical and horizontal rack-work motions . | 15 | 15 | 0 |

2. *The* 3½ *feet Achromatic Telescope.*—The object-glass of this telescope is from 44 to 46 inches focal length, and 2¾ inches diameter. It is generally furnished with four eyepieces, two for terrestrial and two for celestial objects. The lowest power for land objects is generally about 45, which affords a large field of view, and exhibits the objects with great brilliance. The other terrestrial power is usually from 65 to 70. The astronomical powers are about 80 and 130; but such a telescope should always have another eyepiece, to produce a power of 180 or 200 times, which it will bear with distinctness, in a serene state of the atmosphere, if the object-glass be truly achromatic. The *illuminating power* in this telescope is nearly double that of the 2½ feet telescope, or in the proportion of 7.56 to 4, and therefore it will bear about double the magnifying power with nearly equal distinctness. This telescope is fitted up in a manner somewhat similar to the former, with a tripod stand which is placed upon a table. Sometimes, however, it is mounted on a long mahogany stand which rests upon the floor (as in fig. 58,) and is fitted with an equatorial motion; and has generally a small telescope fixed near the eye end of the large tube, called a *finder*, which serves to direct the telescope to a particular object in the heavens when the higher powers are applied. It is likewise eligible that it should have an elevating rack and sliding tubes, for supporting the eye end of the instrument, to keep it steady during astronomical observations, and it would be an advantage, for various purposes which shall be afterward described, to have fitted to it a *diagonal eyepiece* magnifying 40 times or upward.

The prices of this instrument, as marked in Mr. Tulley's catalogue, are as follows:

| | £ | s. | d. |
|---|---|---|---|
| The 3½ feet achromatic telescope, 2¾ inches aperture, on plain pillar and claw stand, 2 eyepieces for astronomical purposes and 1 for land objects, to vary the magnifying power, packed in a mahogany box . . . . . . . | 21 | 0 | 0 |
| Ditto, ditto, with elevating rack and achromatic finder, 2 eyepieces for astronomical purposes and 1 for day objects, to vary the magnifying power, packed in a mahogany box . . . . . . . | 26 | 5 | 0 |

The following are the prices as marked in Messrs. W. and S. Jones's catalogue:

| | £ | s. | d. |
|---|---|---|---|
| The 3½ feet achromatic, plain mahogany tube . . . . | 18 | 18 | 0 |
| Ditto, ditto, brass tube . . | 21 | 0 | 0 |
| Ditto, all in brass, with rack-work motions, &c. . . . | 26 | 5 | 0 |
| Ditto, the object-glass of the largest aperture, and the rack-work motions on an improved principle . . *from* £37 16s. to | 42 | 0 | 0 |
| Ditto, fitted up with equatorial motion, framed mahogany stand, divided altitude and azimuth arches, or declination and right ascension circles, &c., &c., *from* £60 to | 80 | 0 | 0 |

This is the telescope which I would particularly recommend to astronomical amateurs, whose pecuniary resources do not permit them to purchase more expensive instruments. When fitted up with the eyepieces and powers already mentioned, and with a finder and elevating rack—price 25 guineas—it will serve all the purposes of general observation. By this telescope satisfactory views may be obtained of most of the interesting phenomena of the heavens—such as the spots on the sun—the mountains, vales, and caverns on the lunar surface—the phases of Mercury and Venus—the spots on Mars—the satellites and belts of Jupiter—the ring of Saturn—many of the more interesting nebulæ, and most of the double stars of the second and third classes. When the object-glass of this telescope is accurately figured and perfectly achromatic, a power of from 200 to 230 may be put upon it, by which the division of Saturn's ring might occasionally be perceived. It is more easily managed, and represents objects considerably brighter than reflecting telescopes of the same price and magnifying power, and it is not so apt to be deranged as reflectors generally are. A telescope of a less size would not, in general, be found satisfactory for viewing the objects I have now specified, and for general astronomical purposes. It may not be improper, for the information of some readers, to explain what is meant in Mr. Tulley's catalogue when it is stated that this instrument "has one eyepiece for day objects, *to vary the magnifying power.*" The eyepiece alluded to is so constructed, that by drawing out a tube next the eye you may increase the power at pleasure, and make it to vary say from 40 to 80 or 100 times; so that such a construction of the terrestrial eyepiece (to be afterward explained) serves, in a great measure, the purpose of separate eyepieces. The whole length of the 3½ feet telescope, when the terrestrial eyepiece is applied, is about 4½ feet from the object-glass to the first eyeglass.

When the aperture of the object-glass of this telescope exceeds 2¾ inches, its price rapidly advances.

The following is Mr. Tulley's scale of prices, proportionate to the increase of aperture:

| | £ | s. | d. |
|---|---|---|---|
| 3½ feet telescopes, 3¼ inches aperture, with vertical and horizontal rack-work motions, achromatic finder, 3 eyepieces for astronomical purposes, and one for day objects, to vary the magnifying power, packed in a mahogany box . | 42 | 0 | 0 |
| Ditto, ditto, 3¾ inches diameter, mounted as above . . . | 68 | 5 | 0 |
| Ditto, with universal equatorial instead of pillar and claw stand . | 84 | 0 | 0 |



Here, in the one case, the increase of half an inch in the diameter of the object-glass adds about £16 to the expense, and in the other case no less than £26 5s. The proportion of light in those two telescopes, compared with that of 2¾ inches aperture, is as follows. The square of the 2¾ object-glass is 7.56; that of 3¼, 10.56; and that of the 3¾, 14.06; so that the light admitted by the 3¼ compared with the 2¾ aperture is nearly as 10 to 7; and the light admitted by the 3¾ object-glass is nearly double that of the 2¾ aperture, and will bear nearly a proportional increase of magnifying power.

3. *The 5 feet Achromatic Telescope.*—The focal length of the object-glass of this telescope is 5 feet 3 inches, and the diameter of its aperture 3 8-10 inches. The usual magnifying powers applied to it are, for land objects 65 times, and for celestial objects 110, 190, 250, and sometimes one or two higher powers. The quantity of light it possesses is not much larger than that of the 3½ feet telescope, with 3¾ inches aperture; but the larger focal length of this telescope is considered to be an advantage, since the longer the focus of the object-glass, the less will be its chromatic and spherical aberrations, and the larger may be the eyeglasses, and the flatter the field of view.

The following are the prices of these telescopes, as marked in Mr. Tulley's catalogue:

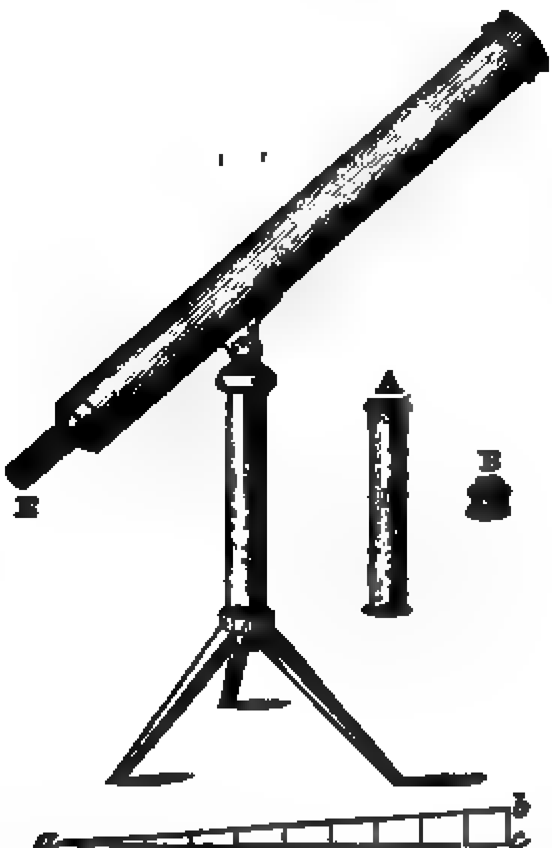
| | £ | s. | d. |
|---|---|---|---|
| 5 feet telescopes, 3¾ inches aperture, on a universal equatorial stand, with achromatic finder, 4 eyepieces for astronomical purposes and 1 for day objects, to vary the magnifying power, packed in a mahogany box 100 guineas to | 157 | 10 | 0 |
| 7 feet ditto, 5 inches aperture, on a newly improved universal equatorial stand, 6 eyepieces for astronomical purposes and 1 for day objects, to vary the magnifying power, with achromatic finder and Troughton's micrometer . . | 207 | 5 | 0 |

The above are all the kinds of achromatic telescopes *generally* made by the London opticians. Those of the larger kind, as 5 and 7 feet telescopes, and the 3½ feet with 3¾ inches aperture, are generally made to order, and are not always to be procured. But the 2½ and 3½ feet achromatics of 2¾ inches aperture are generally to be found ready made at most of the opticians' shops in the metropolis. The prices of these instruments are nearly the same in most of the opticians' shops in Lon

don. Some of them demand a higher price, but few of them are ever sold lower than what has been stated, unless in certain cases where a discount is allowed.

The stands for these telescopes, and the manner in which they are fitted up for observation, is represented in figures 57, 58, and 59. Fig. 57 represents either the $2\frac{1}{2}$ or the

Fig 57




$3\frac{1}{2}$ feet telescopes, mounted on a plain brass stand, to be placed on a table, *A* is the long eyepiece for land objects, and *B* the small eyepiece for astronomical observation, which is composed of two lenses, and represents the object in an inverted position. These eyepieces are screwed on, as occasion requires, at *E*, the eye end of the telescope. The shorter of the two astronomical eyetubes which accompany this telescope produces the highest magnifying power. For adjusting the telescope to distinct vision, there is a brass knob or button at *a*, which moves a piece of rack-work connected with the eyetube, which must be turned either one way or the other till the object appears distinctly, and different eyes frequently require a different adjustment.

Fig. 58 represents a 5 feet telescope fitted up for astronomical observations. It is mounted on a mahogany stand, the three legs of which are made to close up together by means of the brass frame *a a a*, which is composed of three bars, connected with three joints in the centre, and three other joints, connected with the three mahogany bars. It is furnished with an apparatus for equatorial motions. The brass pin is made to move round in the brass socket *b*, and may be tightened by means of the finger screw *d*, when the telescope is directed nearly to the object intended to be viewed. This socket may be set perpendicular to the horizon, or to any other required angle; and the quantity

Fig. 58.


of the angle is ascertained by the divided arc, and the instrument made fast in that position by the screw *e*. If this socket be set to the latitude of the place of observation, and the plane of this arc be turned so as to be in the plane of the meridian, the socket *b* being fixed to the inclination of the pole of the earth, the telescope, when turned in this socket, will have an equatorial motion, so that celestial objects may be always kept in view when this equatorial motion is performed. The two handles at *k*, are connected with rack-work, intended to move the telescope in any required direction. The two sets of brass sliding rods, *i i*, are intended to render the telescope as steady as possible, and to elevate and depress it at pleasure, and are so constructed as to slide into each other with the utmost ease.

The *finder* is placed at *A E*, either on the top or the left side of the tube of the telescope. When high magnifying powers are applied to any telescope, it is sometimes difficult, on account of the smallness of the field of view, to direct the main tube of the telescope to the object. But the finder, which is a telescope with a small power, and consequently has a large field of view, when directed to any ob-

ject, it is easily found, and being brought to the centre of the field, where two cross-hairs intersect each other, it will then be seen in the larger telescope. *B* is the eyetube for terrestrial objects, containing four glasses, and *C* one of the astronomical eyepieces. A socket is represented at *g*, containing a stained glass, which is screwed to any of the eye-pieces, to protect the eye from the glare of light, when viewing the spots of the sun. The brass nut above *f* is intended for the adjustment of the eyepiece to distinct vision. The 3½ feet telescope is sometimes mounted in this form.

Fig. 59 represents a 5 or 6 feet telescope,

Fig. 59.

mounted on a stand of a new construction by Dollond. It possesses the advantage of supporting the telescope in two places, which renders it extremely steady, a property of great importance when viewing celestial objects with high magnifying powers. It possesses, likewise, the advantage of enabling the observer to continue seated at the same height from the floor, although the telescope be raised to any altitude, *the elevation being entirely at the object end*, although it may be changed from the horizon to the zenith. The framework is composed of bars of mahogany, and rests on three castors, two of which are made fast to their respective legs in the usual way, and the third stands under the middle of the lower horizontal bar that connects the two opposite legs, so that the frame has all the advantages of a tripod. As it becomes very inconvenient to stoop to the eye end of a telescope when the altitude of an object is considerable, and the centre of motion at the middle of the tube, this construction of a stand serves to remedy such inconvenience.

*Proportions of Curvature of the Lenses which form an achromatic Object-glass.*

As some ingenious mechanics may feel a desire to attempt the construction of a compound achromatic object-glass, I shall here state some of the proportions of curvature of the concave and convex lenses which serve to guide opticians in their construction of achromatic instruments. These proportions are various; and even when demonstrated to be mathematically correct, it is sometimes difficult to reduce them to practice, on account of the different powers of refraction and dispersion possessed by different disks of crown and flint glass, and of the difficulty of producing by mechanical means the exact curves which theory requires. The following table shows the radii of curvature of the different surfaces of the lenses necessary to form *a double achromatic object-glass*, it being supposed that the sine of refraction in the crown-glass is as 1.528 to 1, and in the flint as 1.5735 to 1, the ratio of their dispersive powers being as 1 to 1.524. It is also assumed that the curvatures of the concave lens are as 1 to 2, that is, that the one side of this lens is ground on a tool, the radius of which is double that of the other. The 1st column expresses the compound focus of the object-glass in *inches*; the 2d column states the radius of the *anterior* surface of the *crown*, and column 3d its *posterior* side. Column 4th expresses the radius of the anterior surface of the *concave* lens, and column 5th its posterior surface, which, it will be observed, is exactly double that of the other:

| Focus in inches. | Radius of anterior surface, convex. | | Radius of posterior surface. | | Radius of anterior surface, concave. | | Radius of posterior surface. | |
|---|---|---|---|---|---|---|---|---|
| | Inc. | Dec. | Inc. | Dec. | Inc. | Dec. | Inc. | Dec. |
| 12 | 3 | | 4. | 659 | 4. | 171 | 8. | 342 |
| 24 | 6 | | 9. | 304 | 8. | 342 | 16. | 684 |
| 30 | 7. | 5 | 11. | 63 | 10. | 428 | 20. | 856 |
| 36 | 9 | | 13. | 956 | 12. | 513 | 25. | 027 |
| 48 | 12 | | 18. | 608 | 16. | 684 | 33. | 369 |
| 60 | 15 | | 23. | 260 | 20. | 856 | 41. | 712 |
| 120 | 30 | | 46. | 520 | 41. | 712 | 83. | 424 |

From the preceding table it will be seen that, to construct, for example, a 30 inch compound object-glass, the radius of the anterior side of the crown must be $7\frac{1}{2}$ inches, and that of the posterior side 11.63 inches; the radius of the anterior surface of the concave 10.428, and that of the posterior 20.856 inches. It may be proper to observe, that in these computations, the radius of the anterior surface of the concave is less than the posterior side of the convex, and consequently admits of its approach, without touching in the centre—a circumstance which always requires to be guarded against in the combination of achromatic glasses. The following table shows the radii of curvature of the lenses of a *triple* object-glass, calculated from formula deduced by Dr. Robison, of Edinburgh:

| Focal length. | Convex lens of crown glass. | | | | Concave lens of flint glass. | | | | Convex lens of crown glass. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inches. | Inc. | Dec. | Inc. | Dec. | Inc. | Dec. | Inc. | Dec. | Inc. | Dec. | Inc. | Dec. |
| 6 | 4. | 54 | 3. | 03 | 3. | 03 | 6. | 36 | 6. | 36 | . | 64 |
| 9 | 6. | 83 | 4. | 56 | 4. | 56 | 9. | 54 | 9. | 54 | . | 92 |
| 12 | 9. | 25 | 6. | 17 | 6. | 17 | 12. | 75 | 12. | 75 | 1. | 28 |
| 18 | 13. | 67 | 9. | 12 | 9. | 12 | 19. | 08 | 19. | 08 | 1. | 92 |
| 24 | 18. | 33 | 12. | 25 | 12. | 25 | 25. | 50 | 25. | 50 | 2. | 56 |
| 30 | 22. | 71 | 15. | 16 | 15. | 16 | 31. | 79 | 31. | 79 | 3. | 20 |
| 36 | 27. | 33 | 18. | 25 | 18. | 25 | 38. | 17 | 38. | 17 | 3. | 84 |
| 42 | 31. | 87 | 21. | 28 | 21. | 28 | 44. | 53 | 44. | 53 | 4. | 48 |
| 48 | 36. | 42 | 24. | 33 | 24. | 33 | 50. | 92 | 50. | 92 | 6. | 12 |
| 54 | 40. | 96 | 27. | 36 | 27. | 36 | 57. | 28 | 57. | 28 | 5. | 76 |
| 60 | 45. | 42 | 30. | 33 | 30. | 33 | 63. | 58 | 63. | 58 | 6. | 4 |

The following table contains the proportions of curvature said to be employed by the London opticians:

| Focal length. | Convex of crown glass. | | | | Radius of both the surfaces of the concave of flint glass. | | Convex lens of crown glass. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Inches. | Inc. | Dec. | Inc. | Dec. | Inc. | Dec. | Inc. | Dec. | Inc. | Dec. |
| 6 | 3. | 77 | 4. | 49 | 3. | 47 | 3. | 77 | 4. | 49 |
| 9 | 5. | 65 | 6. | 74 | 5. | 21 | 5. | 65 | 6. | 74 |
| 12 | 7. | 54 | 8. | 99 | 6. | 95 | 7. | 54 | 8. | 99 |
| 18 | 11. | 30 | 13. | 48 | 10. | 42 | 11. | 30 | 13. | 48 |
| 24 | 15. | 08 | 17. | 98 | 13. | 90 | 15. | 08 | 17. | 98 |
| 36 | 22. | 61 | 26. | 96 | 20. | 84 | 22. | 61 | 26. | 96 |
| 42 | 26. | 38 | 31. | 45 | 24. | 31 | 26. | 38 | 31. | 45 |
| 48 | 30. | 16 | 35. | 96 | 27. | 80 | 30. | 16 | 35. | 96 |
| 54 | 33. | 91 | 40. | 45 | 31. | 27 | 33. | 91 | 40. | 45 |
| 60 | 37. | 68 | 44. | 94 | 34. | 74 | 37. | 68 | 44. | 94 |

From this table it appears that the two convex lenses have the same radii of their respective sides, and that the concave flint lens has its two surfaces equally concave, so that a triple object-glass formed according to these proportions would require only three pair of grinding tools. The following are the curves of the lenses of one of the best of Dollond's achromatic telescopes, the focal length of the compound object-glass being 46 inches. Reckoning from the surface next the object, the radii of the crown glass were 28 and 40 inches; the concave lens 20.9 inches, and the inner crown glass lens 28.4 and 28.4 inches. This telescope carried magnifying powers of from 100 to 200 times.

Although I have inserted the above tables, which might, in some measure, guide an ingenious artist, yet, on the whole, a private amateur has little chance in succeeding in such attempts. The diversity of glasses, and the uncertainty of an unpractised workman's producing the precise curvature he intends, is so great, that the object-glass, for the most part, turns out different from his expectations. The great difficulty in the construction is to find the exact proportion of the dispersive powers of the crown and flint glass. The crown is pretty constant, but there are hardly two pots of flint glass which have the same dispersive power. Even if constant, it is difficult to measure it accurately; and an error in this greatly affects the instrument, because the focal distances of the lenses must be nearly as their dispersive powers. In the two preceding tables, the sine of incidence in the crown glass is supposed to be to the sine of refraction as 1.526 to 1; and in the flint glass, as 1.604 to 1. Opticians who make great numbers of lenses, both of flint and crown glass, acquire, in time, a pretty good guess of the nature of the errors which may remain after they have finished an object-glass; and having many lenses intended to be of the same form, but unavoidably differing a little from it, they try several of the concaves with the two convexes, and finding one better than the rest, they make use of it to complete the set. In this way some of the best achromatic telescopes are frequently formed. I have sometimes found, when supplying a concave flint glass to a telescope where it

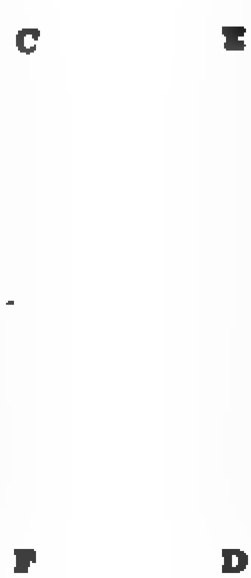
happened to be wanting, that, of four or five concave lenses which appeared to be the same as to curvature and other properties, only one was found to produce a distinct and colourless image. Should any one, however, wish to attempt the construction of an achromatic lens, the best way for preventing disappointments in the result is to procure a *variety* of tables of the respective curvatures founded on *different conditions*, and which, of course, require the surfaces of the several lenses to be of different curves. Having lenses of different radii at his command, and having glass of different refractive or dispersive powers, when one combination does not exactly suit, he may try another, and ultimately may succeed in constructing a good achromatic telescope; for, in many cases, it has been found that chance, or a happy combination of lenses by trial, has led to the formation of an excellent object-glass.

### *Achromatic Telescopes composed of fluid Lenses.*

The best achromatic telescopes, when minutely examined, are found to be in some respects defective, on account of that slight degree of colour which, by the aberration of the rays, they give to objects, unless the object-glass be of small diameter. When we examine with attention a good achromatic telescope, we find that it does not show white or luminous objects perfectly free from colour, their edges being tinged on one side with a claret coloured fringe, and on the other with a green fringe. This telescope, therefore, required further improvement, to get rid of these secondary colours, and Father Boscovich, to whom every branch of optics is much indebted, displayed much ingenuity in his attempts to attain this object. But it is to Dr. Blair, professor of astronomy in Edinburgh, that we are chiefly indebted for the first successful experiments by which this end was accomplished. By a judicious set of experiments, he proved that the quality of dispersing the rays in a greater degree than crown glass is not confined to a few mediums, but is possessed by a great variety of fluids, and by some of these in a most extraordinary degree. Having observed that when the extreme red and violet rays were perfectly united, the green were left out, he conceived the idea of making an achromatic concave lens which should refract the green less than the united red and violet, and an achromatic convex lens which should do the same; and as the concave lens refracted the outstanding green *to* the axis, while the concave one refracted them *from* the axis, it followed that, by a combination of these two opposite effects, the green would be united with the red and violet.

By means of an ingenious prismatic apparatus, he examined the optical properties of a great variety of fluids. The solutions of metals and semi-metals proved in all cases more dispersive than crown glass. Some of the salts, such as sal ammoniac, greatly increased the dispersive power of water. The marine acid disperses very considerably, and this quality increases with its strength. The most dispersive fluids were accordingly found to be those in which this acid and the metals were combined. The chemical preparation called *causticum antimoniale*, or butter of antimony, in its most concentrated state, when it has just attracted sufficient humidity to render it fluid, possesses the quality of dispersing the rays in an astonishing degree. The great quantity of the semi-metal retained in solution, and the highly concentrated state of the marine acid, are considered as the cause of this striking effect. Corrosive sublimate of mercury, added to a solution of *sal ammoniacum* in water, possesses the next place to the butter of antimony among the dispersive fluids which Dr. Blair examined. The essential oils were found to hold the next rank to metallic solutions among fluids which possess the dispersive quality, particularly those obtained from bituminous minerals, as native petrolea, pit coal, and amber. The dispersive power of the essential oil of sassafras, and the essential oil of lemons, when genuine, were found to be not much inferior to any of these. But of all the fluids fitted for optical purposes, Dr. Blair found that *the muriatic acid mixed with a metallic solution*, or, in other words, a fluid in which the marine acid and metalline particles hold a due proportion, most accurately suited his purpose. In a spectrum formed by this fluid, the green were among the most refrangible rays; and when its dispersion was corrected by that of glass, there was produced an inverted secondary spectrum, that is, one in which the green was above, when it would have been below with a common medium. He therefore placed a concave lens of muriatic acid with a metallic solution between the two lenses, as in fig. 60, where *A B* is the concave fluid lens, *C F* a plano-convex lens, with its plane side next the object, and *E D* a meniscus. With this object-glass the rays of different colours were bent from their rectilineal course with the same equality and regularity as in reflection.

Fig. 60.



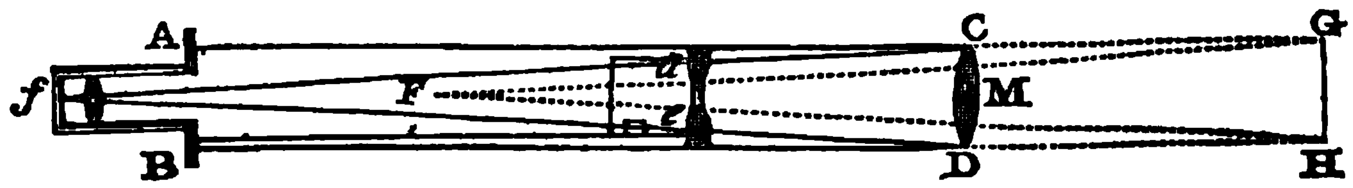
Telescopes constructed with such object-glasses were examined by the late Dr. Robison and Professor Playfair. The focal distance of the object-glass of one of these did not exceed 17 inches, and yet it bore an aperture of 3½ inches. They viewed some single and double stars and some common objects with this telescope, and found that, in magnifying power, brightness, and distinctness, it was manifestly superior to one of Mr. Dollond's of 42 inches focal length. They had most distinct vision of a star, *when using an erecting eyepiece*, which made this telescope magnify more than 100 times, and they found the field of vision as uniformly distinct as with Dollond's 42 inch telescope, magnifying 46 times, and were led to admire the nice figuring and centring of the very deep eye-glasses which were necessary for this amplification. They saw double stars with a degree of perfection which astonished them. These telescopes, however, have never yet come into general use; and one reason, perhaps, is, that they are much more apt to be deranged than telescopes constructed of object-glasses which are solid. If any species of glass, or other solid transparent substance could be found with the same optical properties, instruments might perhaps be constructed of a larger size, and considerably superior to our best achromatic telescopes.* It is said that Mr. Blair, the son of Dr. Blair, some years ago engaged in prosecuting his father's views, but I have not heard any thing respecting the result of his investigations.

### *Barlow's Refracting Telescope with a fluid concave Lens.*

Professor Barlow, not many years ago, suggested a new fluid telescope, which is deserving of attention, and about the year 1829 constructed one of pretty large dimensions. The fluid he employs for this purpose is the *sulphuret of carbon*, which he found to be a substance which possessed every requisite he could desire. Its index is nearly the same as that of the best flint glass, with a dispersive power more than double. It is perfectly colourless, beautifully transparent, and, although very expansible, possesses the same, or very nearly the same, optical properties under all circumstances to which it is likely to be exposed in astronomical observations, except, perhaps, direct observations on the solar disk, which will probably be found inadmissible. Mr. Barlow first constructed an object-glass with this fluid of 3 inches aperture, with which he could see the small star in Polaris with a power of 46, and with the higher powers several stars which are considered to require a good telescope, for example, 70, p Ophinchi, 39 Bootis, the quadruple star ε Lyræ, ζ Aquarii, α Herculis, &c. He next constructed a 6 inch object-glass. With this instrument, the small star in Polaris is so distinct and brilliant, with a power of 143, that its transit might be taken with the utmost certainty. As the mode of constructing these telescopes is somewhat novel, it may be expedient to enter somewhat into detail.

In the usual construction of achromatic telescopes, the two or three lenses composing the object-glass are brought into immediate contact; and in the fluid telescope of Dr. Blair, the construction was the same, the fluid having been inclosed in the object-glass itself. But in Mr. Barlow's telescope, the fluid correcting lens is placed at a distance from the plate lens equal to half its focal length; and it might be carried still further back, and yet possess dispersive power to render the object-glass achromatic. By this means, the fluid lens, which is the most difficult part of the construction, is reduced to one-half, or to less than one-half of the size of the plate lens; consequently, to construct a telescope of 10 or 12 inches aperture involves no greater difficulty in the manipulation than in making

Fig. 61.




a telescope of the usual description of 5 or 6 inches aperture, except in the simple plate lens itself; and, hence, a telescope of this kind of 10 or 12 feet length will be equivalent in its focal power to one of 16 or 20 feet. By this means the tube may be shortened several feet, and yet possess a focal power more considerable than could be conveniently given to it on the usual principle of construction. This will be better understood from the above diagram (fig. 61.)

In this figure *A B C D* represent the tube of the 6 inch telescope, *C D* the plate object-glass, *F* the first focus of rays, *d e* the fluid

* For a more particular account of Dr. Blair's instruments and experiments, the reader is referred to his Dissertation on this subject in vol. ii. of the "Transactions of the Royal Society of Edinburgh," which occupies 76 pages, or to Nicholson's "Journal of Natural Philosophy," &c., quarto series, vol. i. April—September, 1797.

concave lens, distant from the former 24 inches; the focal length $M F$ being 48, and, consequently, as 48 : 6 : : 24 : 3 inches, the diameter of the fluid lens. The resulting compound focus is 62.5 inches. It is obvious, therefore, that the rays $d f$, $e f$, arrive at the focus under the same convergency, and with the same light as if they proceeded from a lens of six inches diameter, placed at a distance beyond the object-glass $C D$ (as $G H$,) determined by producing those rays till they meet the sides of the tube in $G H$, namely, at 62.5 inches beyond the fluid lens. Hence, it is obvious, the rays will converge as they would do from an object glass, $G H$, of the usual kind with a focus of 10 feet 5 inches. We have thus, therefore, shortened the tube 38.5 inches, or have at least the advantage of a focus 38.5 inches longer than our tube; and the same principle may be carried much further, so as to reduce the usual length of refracting telescopes nearly one half, without increasing the aberration in the first glass beyond the least that can possibly belong to a telescope of the usual kind of the whole length. It should likewise be observed, that the adjustment for focus may be made either in the usual way or by a slight movement of the fluid lens, as in the Gregorian Reflectors, by means of the small speculum.

Mr. Barlow afterward constructed another larger telescope on the same principle, the clear aperture of which is $\frac{7}{8}$ inches. Its tube is 11 feet, which, together with the eyepiece, makes the whole length 12 feet, but its effective focus is, on the principle stated, 18 feet. It carries a power of 700 on the closest double stars in South's and Herschel's catalogue, and the stars are, with that power, round and defined, although the field is not then so bright as could be desired. The telescope is mounted on a revolving stand, which works with considerable accuracy as an azimuth and altitude instrument. To give steadiness to the stand, it has been made substantial and heavy, its weight by estimation being 400 pounds, and that of the telescope 130 pounds, yet its motions are so smooth, and the power so arranged, that it may be managed by one person with the greatest ease, the star being followed by a slight touch, scarcely exceeding that of the keys of a piano-forte. The focal length of the plate lens is 78 inches, and of the fluid lens 59.8 inches; which, at the distance of 40 inches, produce a focal length of 104 inches, a total length of 12 feet, and an equivalent focus of 18 feet. The curves of the parallel meniscus checks for containing the fluid are 30 inches and 144 inches, the latter towards the eye. The curves for the plate lens are 56.4 and 144. There is an interior tube 5 inches diameter, and 3 feet 6 inches long, which carries the cell in which the fluid is inclosed, and an apparatus by which it may be moved backward and forward, so that the proper adjustment may be made for colour in the first instance, and afterward the focus is obtained by the usual rack-work motion. The following is the mode by which the fluid was inclosed. After the best position has been determined practically for the checks forming the fluid lens, these, with the ring between them ground and polished accurately to the same curves, are applied together, and taken into an artificial high temperature, exceeding the greatest at which the telescope is ever expected to be used. After remaining here with the fluid some time, the space between the glasses is completely filled, immediately closed, cooled down by evaporation, and removed into a lower temperature. By this means a sudden condensation takes place, an external pressure is brought on the checks, and a bubble formed inside, which is, of course, filled with the vapour of the fluid; the excess of the atmospheric pressure beyond that of the vapour being afterward always acting externally to prevent contact. The extreme edges are then sealed with the serum of human blood, or by strong fish-glue, and some thin, pliable metal surface. By this process, Mr. Barlow says, "I have every reason to believe the lens becomes as durable as any lens of solid glass. At all events, I have the satisfaction of stating, that my first 3 inch telescope has now been completed more than fifteen months, and that no change whatever has taken place in its performance, nor the least perceptible alteration either in the quantity or the quality of the fluid."

The following are some of the observations which have been made with this telescope, and the tests to which it has been subjected. The very small star which accompanies the pole star is generally one of the first tests applied to telescopes. This small point of light appeared brilliant and distinct; it was best seen with a power of 120, but was visible with a power of 700. The small star in Aldebaran was very distinct with a power of 120. The small star $\alpha$ Lyræ was distinctly visible with the same power. The small star called by Sir J. Herschel *Debilissima*, between 4 $\epsilon$ and 5 Lyræ, whose existence, he says, could not be suspected in either the 5 or 7 feet equatorial, and invisible also with the 7 and 10 feet reflectors of six and 9 inches aperture, but seen double with the 20 feet reflector, is seen very satisfactorily double with this telescope. $\eta$ Persei, marked as double in South and Herschel's catalogue, at the distance of 28″, with another small star at the distance of 3′ 67″, is seen distinctly sixfold, four of the small stars being within a considerably less distance

than the remote one of $\eta$ marked in the catalogue. And, rejecting the remote star, the principal and the four other stars form a miniature representation of Jupiter and his satellites, three of them being nearly in a line on one side, and the other on the opposite. *Castor* is distinctly double with 120, and well opened, and stars perfectly round with 360 and 700. $\gamma$ Leonis and $\alpha$ Piscium are seen with the same powers equally round and distinct. In $\varepsilon$ Bootis, the small star is well separated from the larger, and its blue colour well marked with a power of 360. $\eta$ Coronæ Borealis is seen double with a power of 360 and 700. 52 Orionis, $\zeta$ Orionis, and others of the same class, are also well defined with the same powers. In regard to the planets which happened to be visible, Venus appeared beautifully white and well defined with a power of 120, but showed some colour with 360. Saturn, with the 120 power, is a very brilliant object, the double ring and belts being well and satisfactorily defined, and with the 360 power it is still very fine. The moon also is remarkably beautiful, the edges and the shadows being well marked, while the quantity of light is such as to bring to view every minute distinction of figure and shade.

The principal objections that may be made to this construction of a telescope are such as these: Can the fluid be permanently secured? Will it preserve its transparency and other optical properties? Will it not act upon the surface of the glass and partially destroy it? &c. To such inquiries Mr. Barlow replies, that experience is the only test we have; our spirit levels, spirit thermometers, &c., show that some fluids, at least, may be preserved for many years without experiencing any change, and without producing any in the appearance of the glass tubes containing them. But should any of these happen, except the last, nothing can be more simple than to supply the means of replacing the fluid at any time, and by any person, without disturbing the adjustment of the telescope. He expresses his hope that, should these experiments be prosecuted, an achromatic telescope shall ultimately be produced which shall exceed in aperture and power any instruments of the kind hitherto attempted. If the prejudice against the use of fluids could be removed, he feels convinced that well-directed practice would soon lead to the construction of the most perfect instruments, on this principle, at a comparatively small expense. "I am convinced," he says, "judging from what has been paid for large object-glasses, that my telescope, telescope stand, and the building for observation, with every other requisite convenience, have been constructed for a less sum than would be demanded for the object-glass only, if one could be produced of the same diameter of plate and flint glass; and this is a consideration which should have some weight, and encourage a perseverance in the principle of construction."*

### ROGERS'S ACHROMATIC TELESCOPE ON A NEW PLAN.

The object of this construction is to render a small disk of flint glass available to perform the office of compensation to a much larger one of crown glass, and thus to render possible the construction of telescopes of much larger aperture than are now common, without hindrance from the difficulty at present experienced in procuring large disks of flint glass. It is well known to those who are acquainted with telescopes, that in the construction of an ordinary achromatic object-glass, in which a single crown lens is compensated by a single one of flint the two lenses admit of being separated only by an interval too small to afford any material advantage, *in diminishing the diameter of the flint lens*, by placing it in a narrow part of the cone of rays, the actual amount of their difference in point of dispersive power being such as to render the correction of the chromatic aberration impossible when their mutual distance exceeds a certain limit. This inconvenience Mr. Rogers proposes to obviate by employing, as a correcting lens, not a single lens of flint, but a compound one consisting of a convex crown and concave flint, whose foci are such as to cause their combination to act as a plain glass on the mean refrangible rays. Then it is evident that by means of the greater dispersive power of flint than of crown glass, this will act as a concave on the violet, and as a convex on the red rays, and *that* the more powerfully, according as the lenses separately have greater powers or curvature. If then, such a compound lens be interposed between the object-glass of a telescope—supposed to be a single lens of plate or crown glass—and its focus, it will cause no alteration in the focus for mean rays, while it will lengthen the focus for violet, and shorten it for red rays. Now this is precisely what is wanted to produce an achromatic union of all the rays in the focus; and as nothing in this construction limits the powers of the individual correcting lenses,

* A more detailed account of the processes connected with the construction of this telescope will be found in a paper presented to the Royal Society in 1827, and published in the Philosophical Transactions of that Society for 1828, and likewise another paper, published in the Transactions for 1829. From these documents, chiefly, the preceding account has been abridged. See also the "Edinburgh New Philosophical Journal" for Jan.—April, 1828, and Brewster's "Edinburgh Journal of Science" for October, 1829.

they may therefore be applied any where that convenience may dictate; and thus, theoretically speaking, a disk of flint glass, however small, may be made to correct the colour of one of crown, however large.

This construction likewise possesses other and very remarkable advantages: for, first, when the correcting lens is approximately constructed on a calculation founded on its intended aperture, and on the refractive and dispersive indices of its materials, the final and complete dispersion of colour may be effected, not by altering the lenses by grinding them anew, but by shifting the combination nearer to, or further from the object-glass, as occasion may require, along the tube of a telescope, by a screw motion, till the condition of achromaticity is satisfied in the best manner possible; and, secondly, the spherical aberration may in like manner be finally corrected, by slightly separating the lenses of the correcting glass, whose surfaces should for this purpose be figured to curvatures previously determined by calculation to admit of this mode of correction—a condition which Mr. Rogers finds to be always possible. The following is the rule which he lays down for the determination of the foci of the lenses of the correcting glass: "The focal length of either lens is to that of the object-glass in a ratio compounded of the ratio of the square of the aperture of the correcting lens to that of the object-glass, and of the ratio of the difference of the dispersive indices of the crown and flint glass to the dispersive index of crown." For example, to correct the colour of a lens of crown or plate glass of 9 inches aperture and 14 feet focal length (the dimensions of the telescope of Fraunhofer at Dorpat) by a disk of flint glass 3 inches in diameter, the focus of either lens of the correcting lens will require to be about 9 inches. To correct it by a 4 inch disk will require a focus of about 16 inches each.

Mr. Rogers remarks, that it is not indispensable to make the correcting glass act as a plane lens. It is sufficient if it be so adjusted as to have a shorter focus for red rays than for violet. If, preserving this condition, it be made to act as a concave lens, the advantage procured by Mr. Barlow's construction of reducing the length of the telescope with the same focal power is secured, and he considers, moreover, that by a proper adaptation of the distances, foci, &c., of the lenses, we might hope to combine with all these advantages that of the destruction of the secondary spectrum, and thus obtain a perfect telescope.

The above is an abstract of a paper read to the "Astronomical Society of London" in April, 1828, by A. Rogers, Esq.

The reader will easily perceive that the principle on which Mr. Rogers proposes to construct his telescope is very nearly similar to that of Professor Barlow, described above, with this difference, that the correcting lens of the professor's telescope is composed of a transparent *fluid*, while that of Mr. Rogers is a *solid* lens consisting of a convex crown and concave flint. The general object intended to be accomplished by both is the same, namely, to make a correcting lens of a comparatively small diameter serve the purpose of a large disk of flint glass, which has hitherto been very expensive, and very difficult to be procured; and likewise to reduce the length of the telescope, while the advantage of a long focal power is secured. A telescope on this principle was constructed seven or eight years ago by Mr. Wilson, lecturer on Philosophy and Chemistry, Glasgow, before he was aware that Mr. Rogers had proposed a similar plan. I have had an opportunity of particularly inspecting Mr. Wilson's telescope, and trying its effects on terrestrial objects with high powers, and was, on the whole, highly pleased with its performance. It appeared to be almost perfectly achromatic, and produced a distinct and *well-defined* image of minute distant objects, such as small letters on sign-posts, at two, three, and four miles distant; but I had no opportunity of trying its effects on double stars or any other celestial objects. The instrument is above 6 feet long; the object-lens is a plano-convex of crown glass, 4 feet focal distance and 4 inches diameter, the plain side next the object.

At 26 inches distant from the object-lens is the compound lens of 2 inches in diameter; and the two lenses of which it is composed are both ground to a radius of 3¾ inches. That made of crown glass is *plano-convex*, the other, made of flint glass, is plano-concave, and are placed close together, the convex side being next the object, and the concave side next the eye. The greater refractive power of the flint glass renders the compound one slightly concave in its effect (although the radius of curvature is similar in both,) and lengthens the focus to 6 feet from the object-glass; and this is consequently the length of the instrument. The compound corrector so placed intercepts all those rays which go to form the image in the field of view, producing there an achromatic image. The concave power of the corrector renders the image larger than if directly produced by a convex lens of the same focus. The concavity of the corrector is valuable also in this respect, that a very slight alteration in its distance from the object-glass changes the focal distance much more than if it were plain, and enables us to adjust the instrument to perfect achromatism with great precision.

# CHAPTER V.

## *On Reflecting Telescopes.*

### SECTION I.

### *History of the invention, and a general description of the construction of these instruments.*

REFLECTING telescopes are those which represent the images of distant objects by reflection, chiefly from concave mirrors.

Before the achromatic telescope was invented there were two glaring imperfections in refracting telescopes, which the astronomers of the seventeenth century were anxious to correct. The first was its very great length when a high power was to be applied, which rendered it very unwiedly and difficult to use. The second imperfection was the incorrectness of the image as formed by a single lens. Mathematicians had demonstated that a pencil of rays could not be collected in a single point by a spherical lens, and also that the image transmitted by such a lens would be in some degree incurvated. After several attempts had been made to correct this imperfection by grinding lenses to the figure of one of the conic sections, Sir I. Newton happened to commence an examination of the colours formed by a prism; and having, by the means of this simple instrument, discovered the different refrangibility of the rays of light—to which we have several times adverted in the preceding descriptions—he then perceived that the errors of telescopes, arising from that cause alone, were some hundred times greater than such as were occasioned by the spherical figure of lenses, which induced this illustrious philosopher to turn his attention to the improvement of telescopes by reflection.

It is generally supposed that Mr. James Gregory,—a son of the Rev. John Gregory minister of Drumoak, in the county of Aberdeen—was the first who suggested the construction of a reflecting telescope. He was a young man of uncommon genius, and an eminent mathematician; and in the year 1663, at the age of only 24, he published in London his treatise entitled "Optica Promota," in which he explained the theory of that species of reflecting telescope which still bears his name, and which he stated as being his own invention. But as Gregory, according to his own account, was endowed with no mechanical dexterity, and could find no workman capable of realizing his invention, after some fruitless attempts to form proper specula, he was obliged to give up the pursuit, so that this telescope remained for a considerable time neglected. It was several years after Gregory suggested the construction of reflecting telescopes before Newton directed his attention fully to the subject. In a letter addressed to the secretary of the Royal Society, dated in February, 1672, he says, "Finding reflections to be regular, so that the angle of reflection of all sorts of rays was equal to the angle of incidence, I understood that, by their meditation, optic instruments might be brought to any degree of perfection imaginable, providing a reflecting substance could be found which would polish as finely as glass, and reflect as much light as glass transmits, and the art of communicating to it a parabolic figure be also obtained. Amid these thoughts I was forced from Cambridge by the intervening plague, and it was more than two years before I proceeded further."

It was towards the end of 1668, or in the beginning of the following year, when Newton, being obliged to have recourse to reflectors, and not relying on any artificer for making the specula, set about the work himself, and early in the year 1672 completed two small reflecting telescopes. In these he ground the great speculum into a spherical concave, although he approved of the parabolic form, but found himself unable to accomplish it. These telescopes were of a construction somewhat different from what Gregory had suggested, and though only 6 inches long, were considered as equal to a 6 feet common refracting telescope. It is not a little singular, however, that we hear no more about the construction of reflectors till more than half a century afterward. It was not till the year 1723 that any reflectors were known to have been made, adapted to celestial observations. In that year, Mr. Hadley, the inventor of the reflecting quadrant which goes by his name, published, in No. 376 of the Philosophical Transactions, an account of a large reflector on Newton's plan, which he had just then constructed, the performance of which left no room to doubt that this invention would remain any longer in obscurity. The large speculum of this instrument was 62⅝ inches focal distance and 5 inches diameter, was furnished with magnifying powers of from 190 to 230 times, and equalled in performance the famous aërial telescope of Huygens of 123

feet in length.* Since this period the reflecting telescope has been in general use among astronomers in most countries of Europe, and has received numerous improvements, under the direction of Short, Mudge, Edwards, and Herschel, the last of whom constructed reflectors of 7, 10, 20, and even 40 feet in focal length, which far surpassed, in brightness and magnifying power, all the instruments of this description which had previously been attempted.

I shall now proceed to give a brief sketch of the nature of a reflecting telescope, and the different forms in which they have been proposed to be constructed.

Fig. 62 represents the reflecting telescope as originally proposed by Gregory. $A\,B\,E\,F$ represents a tube open at $A\,F$ towards the object; at the other end is placed a concave speculum, $B\,E$, with a hole, $C\,D$, in its centre, the focus of which is at $e$. A little beyond this focus, towards the object end of the telescope, $A\,F$, is placed another small concave mirror, $G$, having its polished face turned towards the great speculum, and is supported by an arm, $G\,H$, fastened to a slider connected with the tube. At the end of the great tube, $B\,E$, is screwed in a small tube, $C\,D\,K\,I$, containing a small plano-convex lens, $I\,K$. Such are the essential parts of this instrument and their relative positions. It will be recollected in our description of the properties of concave mirrors (see p. 28,) that, when rays proceed from a distant object, and fall upon a concave speculum, they paint an image or representation of the object in its focus before the speculum. Now suppose two parallel rays, $a\,b$, falling on the speculum $B\,E$, in $c\,d$; they are reflected to its focus $e$, where an inverted image of the object is formed at a little more than the focal distance of the small speculum from its surface, and serves, as it were, for an object on which the small mirror may act. By the action of this mirror this first image is reflected to a point about $f$, where a second image is formed very large and erect. This image is magnified in the proportion of $f\,G$ to $e\,G$, the rays from which are transmitted to the eyeglass $I\,K$, through which the eye perceives the object clear and distinct, after the proper adjustments have been made.

Fig. 62.

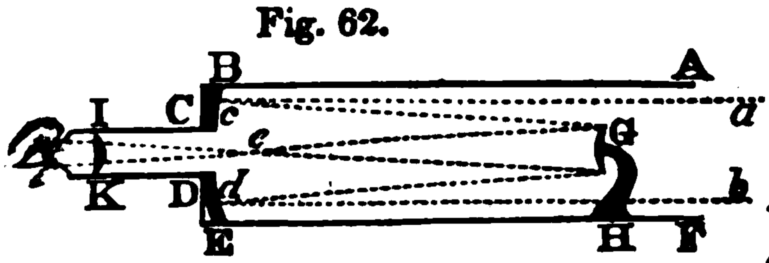


Fig. 63.

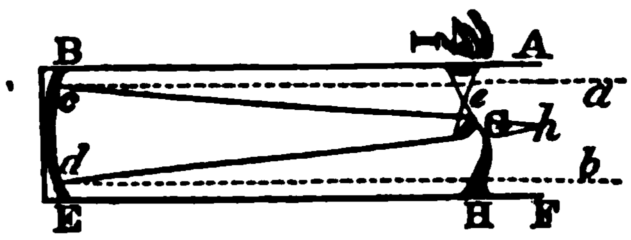


Fig. 64.

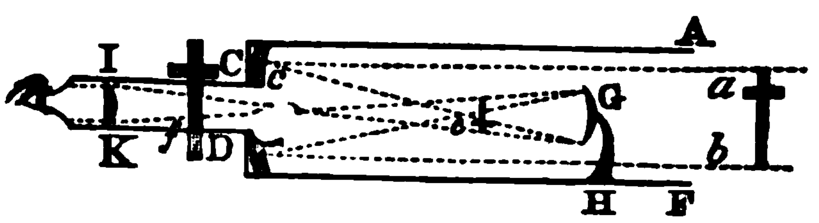


Fig. 65.

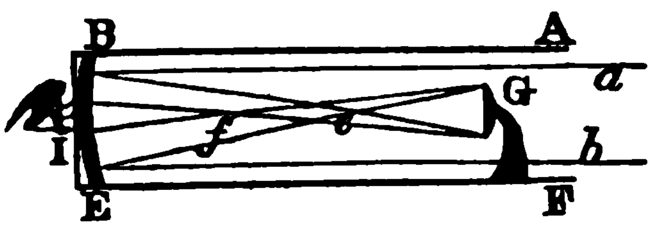
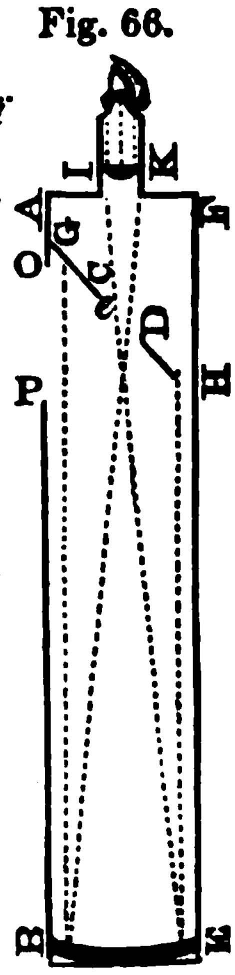


Fig. 66.



Suppose the focal distance of the great mirror was 9 inches, and the focal distance of the small mirror 1½ inch—were we to remove the eyepiece of this telescope, and look through the hole of the great mirror, we should see the image of the object depicted upon the face of the small speculum, and magnified in the proportion of 9 to 1½, or 6 times, on the same principle as a common convex object-glass 9 inches focal length, with an eyeglass whose focus is 1½ inch, magnifies 6 times. This may be regarded as the first part of the magnifying power. If, now, we suppose the small speculum placed a little more than 1½ inch from the image formed by the great speculum, a second image is formed about $f$, as much exceeding the first in its dimensions as it exceeds it in distance from the small speculum, on the principle on which the object-glass of a compound microscope forms a large image near the eyeglass. Suppose this distance to be 9 times greater, then the whole magnifying power will be compounded of 6 multiplied by 9, or 54 times. As a telescope it magnifies 6 times, and in the microscope part 9 times. Such is the *general* idea of the Gregorian telescope, the minute particulars and structure of which can only be clearly perceived by a direct inspection of the instrument.

*The Newtonian Reflector.*—This instrument is somewhat different both in its form and in its mode of operation from that of Gregory. It is represented in fig. 63, where $B\,A\,E\,F$ is the tube, and $B\,E$ the object con

* A particular description of this telescope, with the machinery for moving it, illustrated with an engraving, may be seen in Reid and Gray's "Abridgment of the Philosophical Transactions," vol. vi. Part I for 1723, p. 147-152.

cave mirror, which reflects the parallel rays $a$ $b$ to a *plane* speculum $G$, placed 45°, or half a right angle to the axis of the concave speculum. This small plane reflector must be of an oval form; the length of the oval should be to the breadth as 7 to 5, on account of the obliquity of its position. It is supported on an arm fixed to the side of the tube; an eyeglass is placed in a small tube, movable in the larger tube, so as to be perpendicular to the axis of the large reflector, the perpendicular line passing through the centre of the small mirror. The small mirror is situated between the large mirror and its focus, that its distance from this focal point may be equal to the distance from the centre of the mirror to the focus of the eyeglass. When the rays $a$ $b$ from a distant object fall upon the large speculum at $c$ $d$, they are reflected towards a focus at $h$; but, being intercepted by the plane mirror $G$, they are reflected perpendicularly to the eyeglass at $I$, in the side of the tube, and the image formed near that position at $e$ is viewed through a small plano-convex lens. The magnifying power of this telescope is in the proportion of the focal distance of the speculum to that of the eyeglass. Thus, if the focal distance of the speculum be 36 inches, and that of the eyeglass one-third of an inch, the magnifying power will be 108 times. It was this form of the reflecting telescope that Newton invented, which Sir W. Herschel adopted, and with which he made most of his observations and discoveries.

*The Cassegrainian Reflector.*—This mode of the reflecting telescope, suggested by M. Cassegrain, a Frenchman, is represented in fig. 64. It is constructed in the same way as the Gregorian, with the exception of a small *convex* speculum, $G$, being substituted in the room of the small concave in Gregory's construction. As the focus of a convex mirror is negative, it is placed at a distance from the large speculum equal to the difference of their foci; that is, if the focal length of the large speculum be 18 inches, and that of the small convex 2 inches, they are placed at 16 inches distant from each other, on a principle similar to that of the Galilean telescope, in which the concave eyeglass is placed within the focus of the object-glass by a space equal to the focal length of the eyeglass. In this telescope, likewise, instead of two there is only *one image* formed, namely, that in the focus of the eyeglass; and, on this account, some are of opinion that the distinctness is considerably greater than in the Gregorian. Mr. Ramsden was of opinion that this construction is preferable to either of the former reflectors, because the aberrations of the two metals have a tendency to correct each other, whereas in the Gregorian, both the metals being concave, any error in the specula will be doubled. It is his opinion that the aberrations in the Cassegrainian construction to that of the Gregorian is as 3 to 5. The length of this telescope is shorter than that of a Gregorian of equal focal length by twice the focal length of the small mirror, and it shows every thing in an *inverted* position, and, consequently, is not adapted for viewing terrestrial objects.

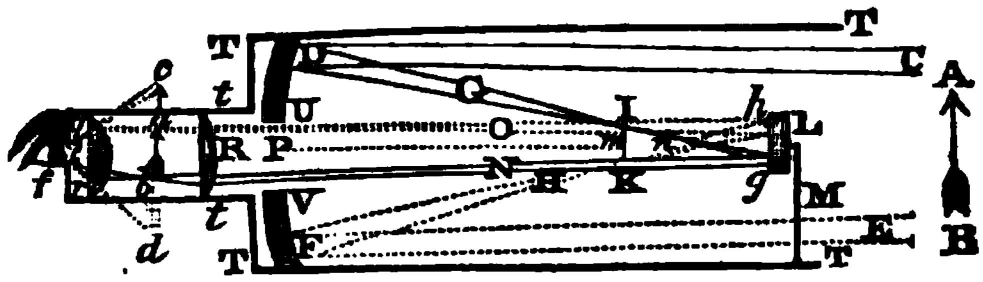
*Dr. Hook's Reflector.*—Before the reflecting telescope was much known, Dr. Hook contrived one, the form of which is represented fig. 65, which differs in little or nothing from the Gregorian, except that the eyeglass, $I$, is placed in the hole of the great speculum, $B$ $E$.

*Martin's Reflector.*—Mr. Benjamin Martin, a distinguished writer on optical and philosophical science, about a century ago described a new form of the reflecting telescope, approximating to the Newtonian structure, which he contrived for his own use. It is represented in fig. 66. $A$ $B$ $E$ $F$ is the tube, in which there is an opening or aperture, $O$ $P$, in the upper part. Against this hole, within the tube, is placed a large plane speculum, $G$ $H$, at half a right angle with the axis or sides of the tubes, with a hole, $C$ $D$, perforated through its middle. The parallel rays $a$ $b$, falling on the inclined plane $G$ $H$, are reflected perpendicularly and parallel on the great speculum $B$ $E$ in the bottom of the tube. From thence they are reflected, converging to a focus, $e$, through the hole of the plane mirror $C$ $D$, which being also the focus of the eyeglass $I$ $K$, the eye will perceive the object magnified and distinct.

In the figures referred to in the above descriptions, only one eyeglass is represented, to avoid complexity; but in most reflecting telescopes, the eyepiece consists of a combination of two plano-convex glasses, as in fig. 67, which produces a more correct and a larger field of view than a single lens. This combination is generally known by the name of the *Huygenian Eyepiece*, which shall be described in the section on the *eyepieces* of telescopes.

The following rule has been given for finding the magnifying power of the Gregorian telescope: Multiply the focal distance of the great mirror by the distance of the small mirror from the image next the eye, and mul-

Fig. 67.



tiply the focal distance of the small mirror by the focal distance of the eyeglass; then divide the product of the former multiplication by the product of the latter, and the quotient will express the magnifying power. The following are the dimensions of one of the reflecting telescopes constructed by Mr. Short, who was long distinguished as the most eminent maker of such instruments on a large scale, and whose large reflectors are still to be found in various observatories throughout Europe:

The focal distance of the great mirror, 9.6 inches; or *P m*, fig. 67, its breadth, *F D*, 2.3; the focal distance of the small mirror, *L n*, 1.5, or 1½ inch; its breadth, *g h*, 0.6 or 6-10ths of an inch; the breadth in the hole in the great mirror, *U V*, 0.5, or half an inch; the distance between the small mirror and the next eyeglass, *L R*, 14.2; the distance between the two eyeglasses, *S R*, 2.4; the focal distance of the eyeglass next the metal, 3.8; and the focal distance of the eyeglass next the eye, *S a*, 1.1, or 11-10th of an inch. The magnifying power of this telescope was about 60 times. Taking this telescope as a standard, the following table of the dimensions and magnifying powers of Gregorian reflecting telescopes, as constructed by Mr. Short, has been computed:

| Focal distance of the great mirror. | Breadth of the great mirror. | Focus of the small speculum. | Breadth of the hole in the great speculum. | Distance between the small speculum and the first eye-glass. | Focal distance of the glass next the metals. | Focal distance of the glass next the eye. | Distance between the plain sides of the two glasses. | Magnifying power. | Distance between the second glass and the small eye hole. |
|---|---|---|---|---|---|---|---|---|---|
| P m | D F | L n | U V | L R | R | S | R S | | |
| In. Dec. | In. Dec. | In. Dec. | In. Dec. | In. Dec. | In. Dec. | In. Dec. | In. Dec. | In. | |
| 5. 65 | 1. 54 | 1. 10 | 0. 31 | 8. 54 | 2. 44 | 0. 81 | 1. 68 | 39 | 0. 41 |
| 9. 60 | 2. 30 | 1. 50 | 0. 39 | 14. 61 | 3. 13 | 1. 04 | 2. 09 | 60 | 0. 52 |
| 15. 50 | 3. 30 | 2. 14 | 0. 50 | 23. 81 | 3. 94 | 1. 31 | 2. 63 | 86 | 0. 66 |
| 36. 00 | 6. 26 | 3. 43 | 0. 65 | 41. 16 | 5. 12 | 1. 71 | 3. 41 | 165 | 0. 85 |
| 60. 00 | 9. 21 | 5. 00 | 0. 85 | 68. 17 | 6. 43 | 2. 14 | 4. 28 | 243 | 1. 87 |

Mr. Short—who was born in Edinburgh in 1710, and died near London, 1768—was considered as the most accurate constructor of reflecting telescopes during the period which intervened from 1732 to 1768. In 1743 he constructed a reflector for Lord Thomas Spencer, of 12 feet focal length, for which he received 600 guineas. He made several other telescopes of the same focal distance, with greater improvements and higher magnifiers; and, in 1752, finished one for the King of Spain, for which, with its whole apparatus, he received £1200. This was considered the noblest instrument of its kind that had then been constructed, and perhaps it was never surpassed till Herschel constructed his twenty and forty feet reflectors. High as the prices of large telescopes now are, Mr. Short charged for his instruments at a much higher rate than opticians now do, although the price of labour, and every other article required in the construction of a telescope is now much dearer. But he had then scarcely any competitor, and he spared neither trouble nor expense to make his telescopes perfect, and put such a price upon them as properly repaid him. The following table contains a statement of the apertures, powers, and prices of Gregorian telescopes, as constructed by Mr. James Short:*

| Number. | Focal length in inches. | Diameter of aperture in inches. | Magnifying powers. | | | Prices in guineas. |
|---|---|---|---|---|---|---|
| 1 | 3 | 1.1 | 1 Power of | 18 | times | 3 |
| 2 | 4½ | 1.3 | 1 " | 25 | " | 4 |
| 3 | 7 | 1.9 | 1 " | 40 | " | 6 |
| 4 | 9½ | 2.5 | 2 Powers | 40 and 60 | " | 8 |
| 5 | 12 | 3.0 | 2 " | 55 and 85 | " | 10 |
| 6 | 12 | 3.0 | 4 " | 35, 55, 85, and 110 | " | 14 |
| 7 | 18 | 3.8 | 4 " | 55, 95, 130, and 200 | " | 20 |
| 8 | 24 | 4.5 | 4 " | 90, 150, 230, and 300 | " | 35 |
| 9 | 36 | 6.3 | 4 " | 100, 200, 300, and 400 | " | 75 |
| 10 | 48 | 7.6 | 4 " | 120, 260, 380, and 500 | " | 100 |
| 11 | 72 | 12.2 | 4 " | 200, 400, 600, and 800 | " | 300 |
| 12 | 144 | 18 0 | 4 " | 300, 600, 900, and 1200 | " | 800 |

From this table it appears that Mr. Short charged 75 guineas for a 3 feet reflector, whereas such an instrument is now marked in the London opticians' catalogues at £23 when mounted on a common brass stand, and £39 18*s.* when accompanied with rack-work motions and other apparatus. It is now generally understood that in the above table Short always greatly *overrated* the higher powers of his telescopes. By experiment, they were

* Miss Short, who has erected and who superintends an observatory on the Calton Hill, Edinburgh, is the descendant of a brother of Mr. Short. She is in possession of a large Gregorian reflector, about 12 feet long, made by Mr. Short, and mounted on an equatorial axis. It was originally placed in a small observatory erected on the Calton Hill about the year 1776, but for many years past it has been little used.

generally found to magnify *much less* than here expressed.

*General Remarks on Gregorian Reflectors.*—1. In regard to the hole, *U V*, of the great speculum, its diameter should be equal, or nearly so, to that of the small speculum, *L*, fig. 67; for if it be less, no more parallel rays will be reflected than if it were equal to *g h*, and it may do harm in contracting the visible area within too narrow limits; nor must it be larger than the mirror *L*, because some parallel rays will then be lost, and those of most consequence, as being nearest the centre. 2. The small hole at *e*, to which the eye is applied, must be nicely adjusted to the size of the cone of rays proceeding from the nearest lens, *S*. If it be larger, it will permit the foreign light of the sky or other objects to enter the eye, so as to prevent distinct vision; for the eye should receive no light but what comes from the surface of the small mirror, *L*. If the hole be smaller than the cylinder of rays at *e*, then some of the necessary light will be excluded, and the object rendered more obscure. The diameter of this hole may be found by dividing the aperture of the telescope in inches by its magnifying power. Thus, if we divide the diameter of one of Short's telescopes, the diameter of whose large speculum is 2.30, by 60, the magnifying power, the quotient will be .0383, which is nearly the $\frac{1}{25}$th of an inch. Sometimes this hole is made so small as the $\frac{1}{50}$th of an inch. When this hole is, by any derangement, shifted from its proper position, it sometimes requires great nicety to adjust it, and, before it is accurately adjusted, the telescope is unfit for accurate observation. 3. It is usual to fix a plate with a hole in it at *a b*, the focus of the eyeglass *S*, of such a diameter as will circumscribe the image, so as to exhibit only that part of it which appears distinct, and to exclude the superfluous rays. 4. There is an adjusting screw on the outside of the great tube, connected with the small speculum, by which that speculum may be pushed backward or forward to adjust the instrument to distinct vision. The hand is applied for this purpose at *T*.

*Newtonian Telescopes.*—These telescopes are now more frequently used for celestial observations than during the last century, when Gregorian reflectors were generally preferred. Sir W. Herschel was chiefly instrumental in introducing this form of the reflecting telescope to the more particular attention of astronomers, by the splendour and extent of the discoveries which it enabled him to make. In this telescope there is no hole required in the middle of the great speculum, as in the Gregorian construction, which circumstance secures the use of all the rays which flow from the central parts of the mirror.

The following table contains a statement of the apertures and magnifying powers of Newtonian telescopes, and the focal distances of their eyeglasses. The first column contains the focal length of the great speculum in feet; the second, its linear aperture in inches; the third, the focal distance of the single glass in decimals, or in 1000ths of an inch, and the fourth column contains the magnifying power. This portion of the table was constructed by using the dimensions of Mr. Hadley's Newtonian telescope, formerly referred to, as a standard, the focal distance of the great mirror being 62½ inches, its medium aperture 5 inches, and power 208. The fifth, sixth, and seventh columns contain the apertures of the concave speculum, the focal lengths of the eyeglasses, and the magnifying powers, as calculated by Sir D. Brewster, from a telescope of Mr. Hauksbee, taken as a standard, whose focal length was 3 feet 3 inches, its aperture about 4 inches, and magnifying power 226 times.

| Focal distance of concave metal. | Aperture of concave metal. | Focal distance of single eyeglass. | Magnifying power. | Sir D. Brewster's Numbers. Aperture of the concave speculum. | Focal length of eyeglass. | Magnifying power. |
|---|---|---|---|---|---|---|
| Feet. | Inc. Dec. | Inc. Dec. | | Inc. Dec. | Inc. Dec. | |
| 0½ | 0. 86 | 0. 167 | 36 | 1. 34 | 0. 107 | 56 |
| 1 | 1. 44 | 0. 199 | 60 | 2. 23 | 0. 129 | 93 |
| 2 | 2. 45 | 0. 236 | 102 | 3. 79 | 0. 152 | 158 |
| 3 | 3. 31 | 0. 261 | 138 | 5. 14 | 0. 168 | 214 |
| 4 | 4. 10 | 0. 281 | 171 | 6. 36 | 0. 181 | 265 |
| 5 | 4. 85 | 0. 297 | 202 | 7. 51 | 0. 192 | 313 |
| 6 | 5. 57 | 0. 311 | 232 | 8. 64 | 0. 200=⅕ | 360 |
| 7 | 6. 24 | 0. 323 | 260 | 9. 67 | 0. 209 | 403 |
| 8 | 6. 89 | 0. 334 | 287 | 10. 44 | 0. 218 | 445 |
| 9 | 7. 54 | 0. 344 | 314 | 11. 69 | 0. 222 | 487 |
| 10 | 8. 16 | 0. 353 | 340 | 12. 65 | 0. 228 | 527 |
| 11 | 8. 76 | 0. 362 | 365 | 13. 58 | 0. 233 | 566 |
| 12 | 9. 36 | 0. 367 | 390 | 14. 50 | 0. 238 | 604 |
| 13 | 9. 94 | 0. 377 | 414 | 15. 41 | 0. 243 | 642 |
| 14 | 16. 49 | 0. 384 | 437 | 16. 25 | 0. 248 | 677 |
| 15 | 11. 04 | 0. 391 | 460 | 17. 11 | 0. 252 | 713 |
| 16 | 11. 59 | 0. 397 | 483 | 17. 98 | 0. 256 | 749 |
| 17 | 12. 14 | 0. 403 | 506 | 18. 82 | 0. 260 | 784 |
| 18 | 12. 67 | 0. 409 | 528 | 19. 63 | 0. 264 | 818 |
| 19 | 13. 20 | 0. 414 | 550 | 20. 45 | 0. 268 | 852 |
| 20 | 13. 71 | 0. 420 | 571 | 21. 24 | 0. 271 | 895 |

104 825)

One great advantage of reflecting telescopes above common refractors is, that they will admit of eyeglasses of a much shorter focal distance, and, consequently, will magnify so much the more, for the rays are not coloured by reflection from a concave mirror, if it be ground to a true figure, as they are by passing through a convex glass, though figured and polished with the utmost exactness. It will be perceived from the above table that the focal length of the eyeglasses is very small, the lowest there stated being only about $\frac{1}{10}$th of an inch, and the highest little more than $\frac{1}{4}$th of an inch focal distance. Sir W. Herschel obtained the high powers which he sometimes put upon his telescopes by using small double convex lenses for eyeglasses, some of which did not exceed the *one fiftieth of an inch* in focal length. When the focal length of the concave speculum and that of the eyeglass are given, the magnifying power is found by dividing the former by the latter, after having reduced the focal length of the concave speculum to inches. Thus the 6 feet speculum, multiplied by 12, produces 72 inches, which, divided by Brewster's number for the focus of the eyeglass = 200, or $\frac{1}{5}$th of an inch, produces a quotient of 360 as the magnifying power. It has been calculated that, if the metals of a Newtonian telescope be worked as exquisitely as those in Sir W. Herschel's 7 feet reflector, the highest power that such a telescope should bear with perfect distinctness will be found by multiplying the diameter of the great speculum in inches by 74, and the focal distance of the single eyeglass may be found by dividing the focal distance of the great mirror by the magnifying power. Thus 6.25—the aperture in inches of Herschel's 7 feet Newtonian—multiplied by 74, is 462½, the magnifying power; and 7 multiplied by 12, and divided by 462, is 50.182 of an inch, the focal distance of the single eyeglass required. But it is seldom that more than one-half of this power can be applied with effect to any of the planetary bodies. For general purposes, the power produced by multiplying the diameter of the speculum by 30 or 40 will be found most satisfactory.

The following are the general prices of reflecting telescopes as made by the London opticians.

| | £. | s. |
|---|---|---|
| A four feet, seven inch aperture, Gregorian reflector, with the vertical motions upon a new invented principle, as well as apparatus to render the tube more steady in observation, according to the additional apparatus of small speculums, eyepieces, micrometers, &c., *from* 80 to | 120 | 0 |
| Three feet long, mounted on a plain brass stand . . . . | 23 | 2 |
| Ditto, with rack-work motions, improved mounting, and metals . | 39 | 18 |
| Two feet long, without rack-work, and with 4 magnifying powers, improved . . . . . . | 15 | 15 |
| Ditto, with rack-work motion . | 22 | 1 |
| Eighteen inch, on a plain stand . | 9 | 9 |
| Twelve inch, ditto . . . | 6 | 6 |



The above are the prices stated in Messrs. W. and S. Jones's catalogue.

The following list of prices of the various kinds of reflecting telescopes is from Messrs. Tulley's (of Islington) catalogue.

| | £. | s |
|---|---|---|
| 1 foot *Gregorian* reflector, on pillar and claw stand, metal 2½ inches diameter, packed in a mahogany box | 6 | 6 |
| 1½ foot ditto, on pillar and claw stand, metal 3 inches diameter, packed in a mahogany box . . | 11 | 11 |
| 2 feet ditto, metal 4 inches diameter . . . . . . | 16 | 16 |
| Ditto, ditto, with rack-work motions . . . . . . | 25 | 4 |
| 3 feet ditto, metal 5 inches diameter, with rack-work motions . . | 42 | 0 |
| Ditto, metal 6 inches diameter, on a tripod stand, with centre of gravity motion . . . . . . | 68 | 5 |
| 4 feet ditto, metal 7 inches diameter, as above . . . . | 105 | 0 |
| 6 feet ditto, metal 9 inches diameter, on an improved iron stand . | 210 | 0 |
| 7 feet *Newtonian* reflectors, 6 inches aperture, mounted on a new and improved stand . . . | 105 | 0 |
| Ditto, ditto, metal 7 inches diameter . . . . . . . | 126 | 0 |
| 9 feet ditto, metal 9 inches diameter . . . . . . . | 210 | 0 |
| 10 feet ditto, metal 10 inches diameter . . . . . . . | 315 | 0 |
| 12 feet ditto, metal 12 inches diameter . . . . . . . | 525 | 0 |

*Comparative Brightness of Achromatic and Reflecting Telescopes.*—The late astronomer royal, Dr. Maskelyne, from a comparison of a variety of telescopes, was led to the following conclusion: "that the aperture of a common reflecting telescope, in order to show objects as bright as the achromatic, must be to that of an achromatic telescope as 8 to 5;" in other words, an achromatic whose object-glass is 5 inches in diameter, will show objects with as great a degree of brightness as a reflector whose large speculum is 8 inches in diameter. This result, if correct, must be

owing to the small number of rays reflected from a speculum compared with the number transmitted through an achromatic object-glass.

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### Section II.

*The Herschelian Telescope.*

Soon after Sir William Herschel commenced his astronomical career, he introduced a new era in the history of reflecting telescopes. After he had cast and polished an immense variety of specula for telescopes of different sizes, he at length, in the year 1782, finished a 20 feet reflector with a large aperture. Being sensible of the vast quantity of light which is lost by a second reflection from the small speculum, he determined to throw it aside altogether, and mounted this 20 feet reflector on a stand that admitted of being used without a small speculum in making *front observations;* that is, in sitting with his back to the object, and looking directly towards the surface of the speculum. Many of his discoveries and measurements of double stars were made with this instrument, till at length, in the year 1785, he put the finishing hand to that gigantic speculum, which soon became the object of universal astonishment, and which was intended for his *forty-feet* reflecting telescope. He had succeeded so well in constructing reflecting telescopes of comparatively small aperture, that they would bear higher magnifying powers than had ever previously been applied; but he found that a deficiency of light could only be remedied by an increased diameter of the large speculum, which therefore was his main object when he undertook to accomplish a work which to a man less enterprising would have appeared impracticable. The difficulties he had to overcome were numerous, particularly in the operative department of preparing, melting, annealing, grinding, and polishing a mass of metal that was too unwieldy to be moved without the aid of mechanical powers. At length, however, all difficulties having been overcome, this magnificent instrument was completed, with all its complicated apparatus, and erected for observation, on the 28th of August, 1789, and on the same day the sixth satellite of Saturn was detected, as a prelude of still further discoveries which were afterward made by this instrument in the celestial regions.

It would be too tedious to attempt a description of all the machinery and apparatus connected with this noble instrument. The reader who wishes to peruse a minute description of the stairs, ladders, platform, rollers, and of every circumstance relating to joiner's work, carpenter's work, smith's work, and other particulars connected with the formation and erection of this telescope, will find the details recorded in the 85th volume of the Philosophical Transactions of the Royal Society of London for 1795, in which there are sixty-three pages of letter-press, and eighteen plates illustrative of the subject. I shall content myself with giving a short outline of the essential parts belonging to this instrument.

The *tube* of this telescope is made of rolled or sheet iron, joined together without rivets; the thickness of the sheets is somewhat less than $\frac{1}{48}$th part of an inch, or 14 pounds weight for a square foot. Great care was taken that the cylindrical form should be secured, and the whole was coated over three or four times with paint, inside and outside, to secure it against the damp. This tube was removed from the place in which it was formed by 24 men, divided into six sets, so that two men on each side, with a pole 5 feet long in their hands, to which was affixed a piece of coarse cloth 7 feet long, going under the tube, and joined to a pole 5 feet long in the hands of two other men, assisted in carrying the tube. The *length* of this tube is 39 feet 4 inches, the diameter 4 feet 10 inches; and, on a moderate computation, it was ascertained that a wooden tube of proper dimensions would have exceeded an iron one in weight by at least 3000 pounds. Reckoning the circumference of the tube 15 feet, its length 39⅓ feet, and 14 lib. for the weight of a square foot, it must have contained 590 square feet, and weighed 8260 pounds. Various hoops were fixed within the tube, and longitudinal bars of iron connecting some of them are attached to the two ends of the tube, by way of bracing the sheets, and preserving the shape perfect, when the pulleys are applied to give the necessary elevation at the upper end, and that the speculum may be kept secure at the lower end. The lower end of the tube is firmly supported on rollers, that are capable of being moved forward or backward by a double rack, connected with a set of wheels and pinions. By an adjustment at the lower extremity of the tube, the speculum is turned to a small inclination, so that the line of collimation may not be coincident with the longitudinal axis of the tube, but may cross the tube diagonally, and meet the eye in the air at about two inches from the edge of the tube, which is the peculiarity of the construction that supersedes the necessity of applying a second reflector. Hence no part of the head of the observer intercepts the incident rays, and the observation is taken with the face looking at the speculum, the back being turned to the object to be observed.

The large speculum is inclosed in a strong iron ring, braced across with bars of iron, and an inclosure of iron, and ten sheets make a case for it. It is lifted by three handles of iron attached to the sides of the ring, and is put into and taken out of its proper place in the tube by the help of a movable crane, running on a carriage, which operation requires great care. The speculum is made of a metallic composition, and is 49½ inches in diameter; but the concave polished surface is only 48 inches, or 4 feet in diameter. Its thickness is 3½ inches; and when it came from the cast its weight was 2118 pounds. The metals for its formation were procured at a warehouse in Thames-street, London, where they kept ingots of two kinds ready made, one of white and the other of bell-metal; and it was composed of two ingots of bell-metal for one of white. It was not to be expected that a speculum of such large dimensions could have a perfect figure imparted to its surface, nor that the curve, whatever it be, would remain identically the same in changes of temperature; therefore we are not surprised when we are told that the magnifying powers used with this telescope seldom exceeded 200, the quantity of light collected by so large a surface being the principal aim of the maker. The raising of the balcony, on which the observer stands, and the sliding of the lower end of the tube, in which the speculum rests, are effected by separate tackles, and require only occasional motions; but the elevation of the telescope requires the main tackle to be employed, and the motion usually given in altitude at once was two degrees; the breadth of the zone in which the observations were made, as the motion of the sphere in right ascension brought the objects into view. A star, however, could be followed for about a quarter of an hour. Three persons were employed in using this telescope, one to work the tackle, another to observe, and a third to mark down the observations. The elevation was pointed out by a small quadrant fixed to the main tube, near the lower end, but the polar distance was indicated by a piece of machinery, worked by a string, which continually indicated the degree and minute on a dial in the small house adjoining, while the time was shown by a clock in the same place, Miss Herschel performing the office of registrar.

At the upper end the tube is open, and directed to the part of the heavens intended for observation, and the observer, standing on the foot-board, looks down the tube, and perceives the object by rays reflected from the speculum through the eyeglass at the opening of the tube. When the telescope is directed to any objects near the zenith, the observer is necessarily at an elevation at least 40 feet from the ground. Near the place of the eyeglass is the end of a tin pipe, into which a mouthpiece may be placed, so that, during an observation, a person may direct his voice into this pipe, while his eye is at the glass. This pipe, which is 1½ inch in diameter, runs down to the bottom of the tube, where it goes into a turning joint, thence into a drawing tube, and out of this into another turning joint, from whence it proceeds, by a set of sliding tubes, towards the front of the foundation timber. Its use is to convey the voice of the observer to his assistants, for at the last place it divides itself into two branches, one going into the observatory, the other into the workman's room, ascending in both places through the floor, and terminates in the usual shape of speaking trumpets. Though the voice passes in this manner through a tube, with many inflections, and through not less than 115 feet, it requires very little exertion to be well understood.

To direct so unwieldly a body to any part of the heavens at pleasure, many mechanical contrivances were evidently necessary. The whole apparatus rests upon rollers, and care was previously taken of the foundation in the ground. This consists of concentrical brick walls, the outermost 42 feet, the innermost 21 feet in diameter, 2 feet 6 inches deep under ground, 2 feet 3 inches broad at the bottom, and 1 foot 2 inches at the top, capped with paving stones 3 inches thick, and 12¾ inches broad.

In the centre is a large post of oak, framed together with braces under ground, and walled fast to brickwork to make it steady. Round this centre the whole frame is moved horizontally by means of 20 rollers, 12 upon the outer and 8 upon the inner wall. The vertical motion is given to the instrument by means of ropes and pulleys, passing over the main beam supported by the ladders. These ladders are 49 feet long, and there is a movable gallery with 24 rollers to ease its motion. There is a staircase intended for persons who wish to ascend into the gallery without being obliged to go up the ladder. The ease with which the horizontal and vertical motions may be communicated to the tube may be conceived from a remark of Sir W. Herschel, that in the year 1789 he several times observed Saturn, two or three hours before and after its meridian passage, with one single person to continue, at his directions, the necessary horizontal and vertical motions.

By this telescope the sixth and seventh satellites of Saturn were discovered, only one of which is within the reach of the 20 feet reflector, or even of a 25 feet instrument. The discovery of the satellites of the planet Uranus,

however, was made by the 20 feet reflector, but only after it had been converted from the Newtonian to the Herschelian construction, which affords a proof of the superiority of the latter construction over the former when the same speculum is used. Never had the heavens before been observed with so extraordinary an instrument as the forty-feet reflector. The nebulosities which are found among the fixed stars in various regions of the heavens appeared almost all to resolve themselves into an innumerable multitude of stars; others, hitherto imperceptible, seemed to have acquired a distinct light. On the entrance of Sirius into the field of the telescope, the eye was so violently affected that stars of less magnitude could not immediately after be perceived, and it was necessary to wait for 20 minutes before these stars could be observed. The ring of Saturn had always before ceased to be visible when its plane was directed towards the earth; but the feeble light which it reflects in that position was enough for Herschel's instrument, and the ring, even then, still remained visible to him.

It has been generally considered that this telescope was capable of carrying a power of 6000 times; and perhaps, for the purpose of an experiment, and for trying its effect on certain objects, such a power may have been applied, in which case the eyeglass must have been only $\frac{8}{75}$ths of an inch focal distance, or somewhat less than $\frac{1}{70}$th of an inch. But such a power could not be generally applied with any good effect to the planetary bodies, and I question much whether any power above 1000 times was ever generally used; for it is the quantity of light which the telescope collects, more than the magnifying power, that enables us to penetrate, with effect, into the distant spaces of the firmament; and hence, as above stated, the power seldom exceeded 200, which, on account of the large diameter of the speculum, would enable the instrument to penetrate into the distant celestial spaces perhaps further than if a power of as many thousands of times had been applied.

Sir John Herschel, who inherits all the science, skill, and industry of his father, some time ago ground and polished a new speculum for the 20 feet tube, formerly noticed, which is connected with a stand, pulleys, and other appendages similar to those above described, though of smaller dimensions. This telescope shows the double stars exceedingly well defined, and was one of the principal instruments used in forming his catalogue of these objects which was presented to the Royal Society, in conjunction with that of Sir James South, about the year 1828. I suppose it is likewise the same telescope with which Sir John lately made his sidereal observations at the Cape of Good Hope.

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### Section III.

*Ramage's large Reflecting Telescope.*

The largest *front view* reflecting telescope in this country, next to Herschel's 40 feet instrument, is that which was erected at the Royal Observatory at Greenwich in the year 1820, by Mr. Ramage, of Aberdeen. The diameter of the concave reflector is 15 inches, and its focal length 25 feet. It is erected on machinery which bears a certain resemblance to that of Herschel's which we have now described, but the mechanical arrangements are greatly simplified, so that the instrument is manageable by an observer without an assistant. The tube is composed of a twelve-sided prism of deal $\frac{5}{8}$ths of an inch thick. At the mouth is a double cylinder of different diameters on the same axis; around this a cord is wound by a winch, and passes up from the small cylinder, over a pulley, and down through another pulley on to the large cylinder. When the winch, therefore, is turned to raise the telescope, the endless cord is unwound from the smaller cylinder and wound on to the larger, the difference of the size of the two cylinders will be double the quantity raised, and a mechanical force to any extent may thus be obtained, by duly proportioning the diameters of the two cylinders: by this contrivance the necessity of an assistant is superseded. The view through this instrument first astonished those observers who had not been accustomed to examine a heavenly body with a telescope possessing so much light, and its performance was deemed quite extraordinary. But when the first impression had subsided, and different trials had been made in different states of the atmosphere, it was discovered that the central portion of the speculum was more perfectly figured than the ring bordering on the extreme edges. When the aperture was limited to ten or twelve inches, the performance as to the distinctness in its defining power was greatly improved, and the light was so brilliant that the astronomer royal was disposed to entertain an opinion that it might equal that of a good achromatic refractor of the same dimensions. When, however, very small and obscure objects are to be observed, the whole light of the entire aperture may be used with advantage on favourable evenings.

The eyepieces adapted to this telescope have powers which magnify the object linearly from 100 to 1500 times, which are competent to

fulfil all the purposes of vision when cleared of aberration. When the telescope is placed in the plane of the meridian, and elevated, together with the gallery, into any required altitude, the *meridianal sweeps*, formerly practised by Sir W. Herschel, and continued by Sir John with great success, in the examination of double stars and nebula, may be managed with great ease.

Mr. Ramage had a telescope of about the same size erected in an open space in Aberdeen, which I had an opportunity of inspecting when I paid a visit to that gentleman in 1833, but cloudy weather prevented my obtaining a view of any celestial bodies through it. He showed me at that time two or three large speculums, from 12 to 18 inches in diameter, which he had finished some time before, and which appeared most beautifully polished. He told me, too, that he had ground and polished them simply with his hand, without the aid of any machinery or mechanical power: a circumstance which, he said, astonished the opticians of London when it was stated, and which they considered as almost incredible. His experience in casting and polishing metals of various sizes during a period of 15 or 16 years, qualified him to prepare specula of great lustre, and with an unusually high polish. It has been asserted that a fifty-feet telescope by Ramage, of 21 inches aperture, was intended to be substituted for the 25 feet instrument erected at Greenwich, and the speculum, it is understood, was prepared, and ready for use, provided the Navy Board was disposed to defray the expense of carrying the plan into execution; but, unfortunately, this ingenious artist was unexpectedly cut off in the midst of his career, about the year 1835.

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## Section IV.

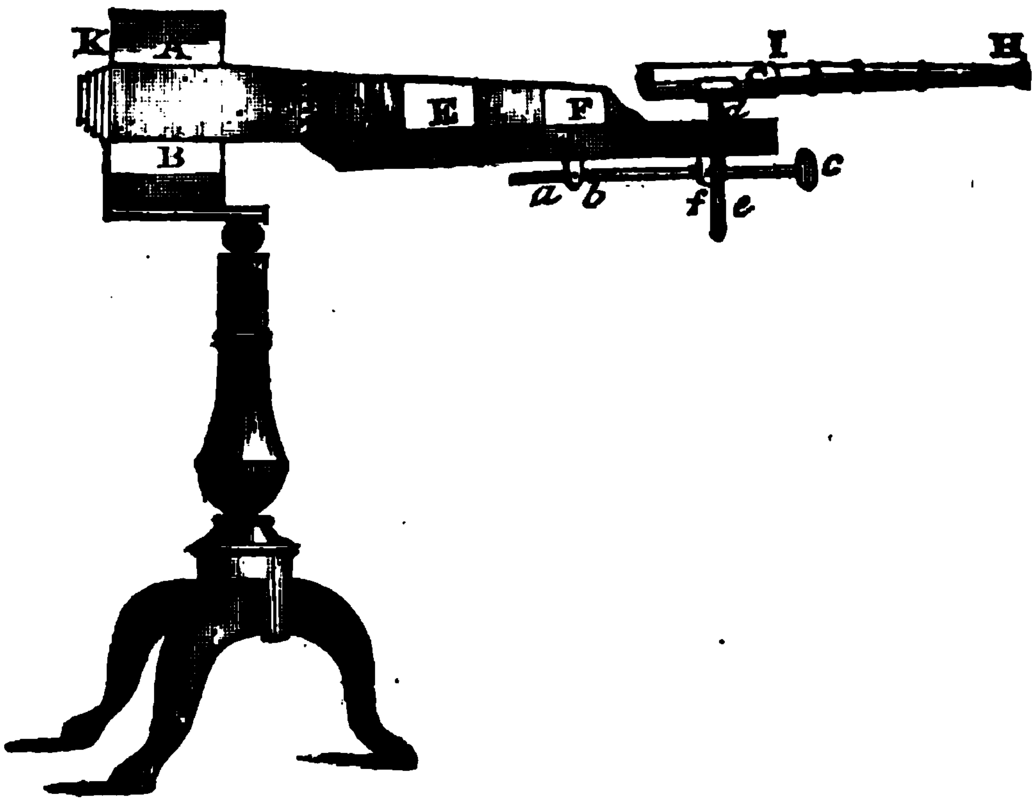
### *The Aerial Reflector constructed by the Author.*

A particular description of this telescope was given in the "Edinburgh New Philosophical Journal" for April—July, 1826, conducted by Professor Jameson, the greater part of which was copied in the "London Encyclopædia," under the article *Telescope*. From this description I shall endeavour to condense a brief account of this instrument, with a few additional remarks.

About the year 1822, an old speculum 27 inches in focal length, very imperfectly polished, happened accidentally to come into my possession, and feeling no inclination to fit it up in the Gregorian form, I adopted the resolution of throwing aside the small speculum, and attempting the *front view*, notwitstanding the uniform assertion of opticians that such an attempt in instruments of a small size is impracticable. I had some ground for expecting success in this attempt from several experiments I had previously made, particularly from some modifications made in the construction of astronomical eyepieces, which have a tendency to correct the aberration of the rays of light when they proceed somewhat obliquely from a lens or speculum. In the first instance, I placed the speculum at one end of a tube of the form of the segment of a cone, the end next the eye being somewhat wider than that at which the speculum was fixed, and its length about an inch shorter than the focal distance of the mirror. A small tube for receiving the different eyepieces was fixed in the inside of the large tube at the end next the eye, and connected with an apparatus by which it could occasionally be moved either in a vertical or horizontal direction. With the instrument fitted up in this manner, I obtained some interesting views of the moon and of terrestrial objects; but, finding that one side of the tube intercepted a considerable portion of light from the object, I determined to throw aside the tube altogether, and to fit up the instrument on a different plan.

A short mahogany tube, about three inches long, was prepared, to serve as a socket for holding the speculum. To the side of this tube an arm was attached, about the length of the focal distance of the mirror, at the extremity of which a brass tube for receiving the eyepieces was fixed, connected with screws and sockets, by which it might be raised or depressed, and turned to the right hand or to the left, and with adjusting apparatus, by which it might be brought nearer to or further from the speculum. Fig. 69 exhibits a general representation of the instrument in profile. *A B* is the short tube which holds the speculum; *C D* the arm which carries the eyetubes, which consists of two distinct pieces of mahogany; the part *D* being capable of sliding along the under side of *C*, through the brass sockets *E F*. To the under part of the socket, *F*, is attached a brass nut with a female screw, in which the male screw, *a b*, acts by applying the hand to the knob *c*, which serves for adjusting the instrument to distinct vision. *G* is the brass tube which receives the eyepieces. It is supported by a strong brass wire, *d e*, which passes through a nut connected with another strong wire, which passes through the arm *D*. By means of the nut *f* this tube may be elevated or depressed, and firmly fixed in its proper position; and by the nut *d* it may be brought nearer to, or further from, the arm *D*.

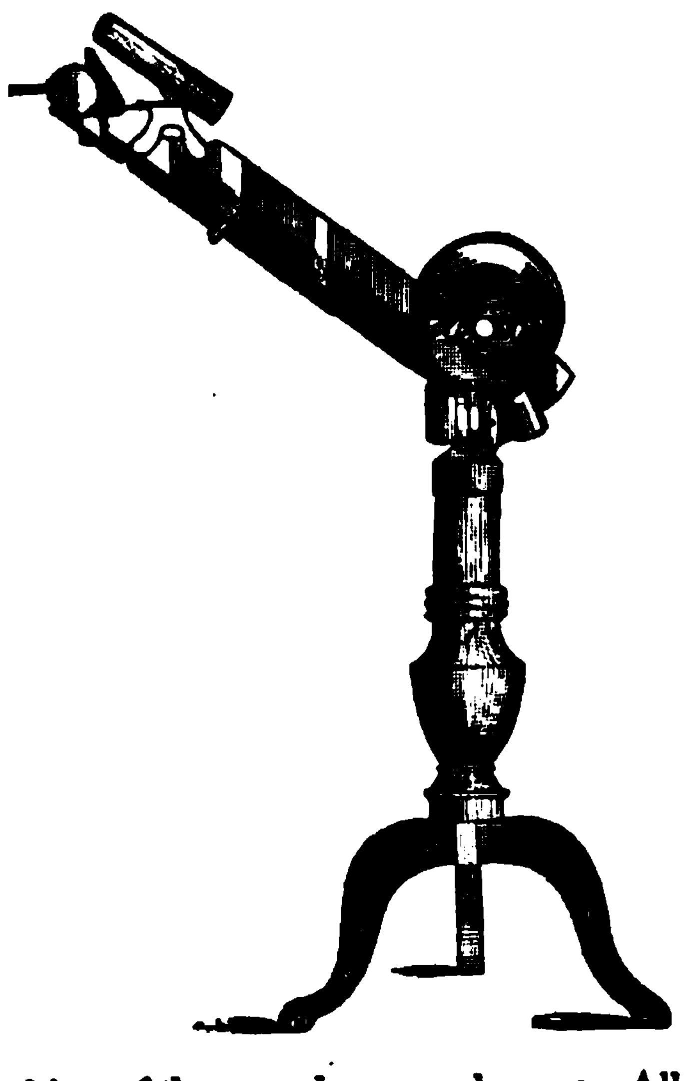
Fig. 69.




By the same apparatus, it is also rendered capable of being moved either in a vertical or horizontal direction; but when it is once adjusted to its proper position, it must be firmly fixed, and requires no further attention. The eyepiece represented in this figure is the one used for terrestrial objects, which consists of the tubes belonging to a pocket achromatic telescope. When an astronomical eyepiece is used, the length of the instrument extends only to the point *I*. In looking through this telescope the right eye is applied at the point *H*, and the observer's head is understood to be uncovered, or, at least, tightly covered with a thin cap. For those who use only the left eye, the arm would require to be placed on the opposite side of the tube, or the arm, along with the tube, be made to turn round 180 degrees.

Fig. 70 represents a front, or, rather, an oblique view of the instrument, in which the

Fig. 70.



position of the speculum may be seen. All the specula which I fitted up in this form, having been originally intended for Gregorian reflectors, have holes in their centres. The eyepiece is therefore directed to a point nearly equidistant from the hole to the left-hand edge of the speculum, that is to the point *a*. In one of these instruments fitted up with a four feet speculum, the line of vision is directed to the point *b* on the opposite side of the speculum, but in this case the eyetube is removed further from the arm than in the former case. The hole in the centre of the speculum is obviously a defect in this construction of a reflecting telescope, as it prevents us from obtaining the full advantage of the rays which fall near the centre of the mirror; yet the performance of the instruments, even with this disadvantage, is superior to what we should previously have been led to expect.

The principal nicety in the construction of the instrument consists in the adjustment and proper direction of the eyetube. There is only one position in which vision will be perfectly distinct. It must be neither too high nor too low; it must be fixed at a certain distance from the arm, and must be directed to a certain point of the speculum. This position must be ultimately determined by experiment when viewing terrestrial objects. A person unacquainted with this construction of the telescope would perhaps find it difficult, in the first instance, to make this adjustment; but were it at any time deranged, through accident or otherwise, I can easily make the adjustment anew in the course of a minute or two.

In pointing this telescope to the object intended to be viewed, the eye is applied at *K*, fig. 69, and looking along the arm, towards the eyepiece, till it nearly coincides with the object, it will, in most cases, be readily found. In this way I can easily point this instrument to Jupiter or Saturn, or to any of the other planets visible to the naked eye, even when a power of 160 or 170 times is applied. When high magnifying powers, however, are used, it may be expedient to fix, on the upper part

of the short tube in which the speculum rests, a finder, such as that which is used in Newtonian telescopes. When the moon is the object intended to be viewed, she may be instantly found by moving the instrument till her reflected image be seen from the eye-end of the telescope on the face of the mirror.

I have fitted up several instruments of the above description with specula of 16, 27, 35, and 49 inches focal distance. One of these, having a speculum of 27 inches focal length, and an astronomical eyepiece producing a maynifying power of about 90 times, serves as a good astronomical telescope. By this instrument the belts and satellites of Jupiter, the ring of Saturn, and the mountains and cavities of the moon, may be contemplated with great ease and distinctness. With a magnifying power of 35 or 40 times, terrestrial objects appear remarkably bright and well defined. When compared with a Gregorian, the quantity of light upon the object appears nearly doubled, and the image is equally distinct, although the speculum has several blemishes, and its surface is but imperfectly polished. It represents objects in their natural colours, without that dingy and yellowish tinge which appears when looking through a Gregorian. Another of these instruments is about four feet long. The speculum which belongs to it is a very old one: when it came into my possession, it was so completely tarnished as scarcely to reflect a ray of light. After it was cleaned, it appeared to be scarcely half polished, and its surface is covered with yellowish stains which cannot be erased. Were it fitted up upon the Gregorian plan, it would, I presume, be of very little use, unless when a very small magnifying power was applied; yet in its present form it bears with distinctness a magnifying power of 130 times, and is equal in its performance to a 3½ feet achromatic. It exhibits distinct and interesting views of the diversities of shade, and of the mountains, vales, cavities, and other inequalities of the moon's surface. With a power of about 50 times, and a terrestrial eyepiece, it forms an excellent telescope for land objects, and exhibits them in a brilliant and novel aspect. The smallest instrument I have attempted to construct on this plan is only 5½ inches focal distance, and 1⅜ths of an inch in diameter. With a magnifying power of about 15 times, it shows terrestrial objects with distinctness and brilliancy. But I should deem it inexpedient to fit up any instrument of this description with specula of a shorter focal distance than 20 or 24 inches. The longer the focal distance, the more distinctness may be expected, although the aperture of the speculum should be comparatively small.



The following are some of the properties and advantages peculiar to this construction of the reflecting telescope:

1. It is *extremely simple*, and may be fitted up at a comparatively *small expense*. Instead of large and expensive brass tubes, such as are used in the Gregorian and Nowtonian construction, little more is required than a short mahogany tube, two or three inches long, to serve as a socket for the speculum, with an arm connected with it about the focal length of the speculum. The expense of small specula, either plain or concave, is saved, together with the numerous screws, springs, &c., for centring the two specula, and placing the small mirror parallel to the large one. The only adjustment requisite in this construction is that of the eyetube to the speculum; and, by means of the simple apparatus above described, it can be effected in the course of a few minutes. Almost the whole expense of the instrument consists in the price of the speculum and the eyepieces. The expense of fitting up the four feet speculum alluded to above, *exclusive of speculum and eyepiece*, but including mahogany tube and arm, brass sockets, screws, eyetube, brass joint, and a cast-iron stand, painted and varnished, did not amount to £1 8*s*. A Gregorian of the same size would have required a brass tube at least 4½ feet in length, which would cost five or six guineas, besides the apparatus connected with the small speculum, and the additional expense connected with the fitting up of the joint and stand requisite for supporting and steadying so unwieldy an instrument. While the one instrument would require two persons to carry it from one room to another, and would occupy a considerable space in an ordinary apartment, the other can be moved, with the utmost ease, with one hand, to any moderate distance, and the space it occupies is extremely small.

2. *It is more convenient for viewing celestial objects at a high altitude than other telescopes.* When we look through a Gregorian reflector or an achromatic telescope of four or five feet in length, to an object elevated 50 or 60 degrees above the horizon, the body requires to be placed in an uneasy and distorted position, and the eye is somewhat strained while the observation is continued; but when viewing similar objects by the *Aerial Reflector*, we can either stand perfectly erect, or sit on a chair, with the same ease as we sit at a desk when reading a book or writing a letter. In this way, the surface of the moon or any other of the planets may be contemplated for an hour or two without the least weariness or fatigue. A delineation of the lunar surface may be taken with this instrument with more ease and ac-

curacy than with any other instrument, as the observer can sketch the outline of the object by one eye on a tablet placed a little below the eyepiece, while the other eye is looking at the object. For the purpose of accommodating the instrument to a sitting or standing posture, a small table was constructed, capable of being elevated or depressed at pleasure, on which the stand of the telescope is placed. When the telescope is four or five feet long, and the object at a very high elevation, the instrument may be placed on the floor of the apartment, and the observer will stand in an erect position.

3. This instrument is considerably *shorter* than a Gregorian telescope whose mirror is of the same focal length. When an astronomical eyepiece is used, the whole length of the instrument is nothing more than the focal length of the speculum; but a Gregorian, whose large speculum is four feet focus, will be nearly five feet in length, including the eyepiece.

4. The Aerial Reflector far excels the Gregorian in brightness. The deficiency of light in the Gregorians is owing to the second reflection from the small mirror; for it has been proved by experiment that nearly the one-half of the rays of light which fall upon a reflecting surface is lost by a second reflection. The image of the object may also be presumed to be more correct, as it is not liable to any distortion by being reflected from another speculum.

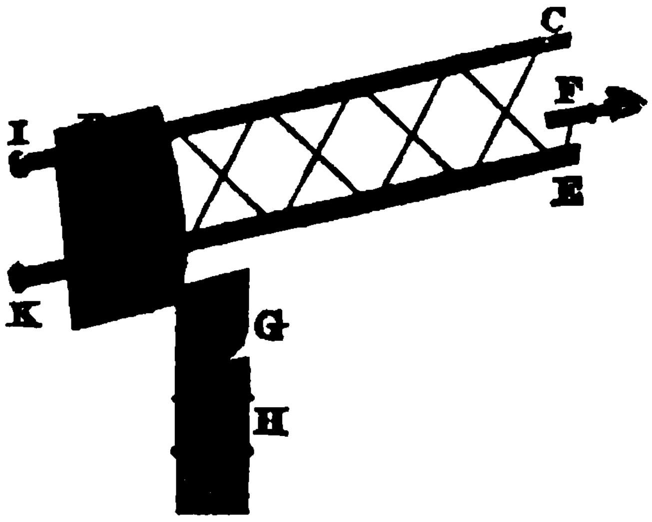
5. There is *less tremor* in these telescopes than in Gregorian reflectors. One cause, among others, of the tremors complained of in Gregorians is, I presume, the formation of a second image at a great distance from the first, besides that which arises from the elastic tremor of the small speculum, when carried by an arm supported only at one end; but as the image formed by the speculum in the aerial telescope is viewed *directly*, without being exposed to any subsequent reflection, it is not so liable to the tremors which are so frequently experienced in other reflectors. Notwithstanding the length of the arm of the four feet telescope above mentioned, a celestial object appears remarkably steady when passing across the field of view, especially when it is at a moderate degree of altitude; and it is easily kept in the field by a gentle motion applied to the arm of the instrument.

In prosecuting my experiments in relation to these instruments, I wished to ascertain what effect might be produced by using a *part of a speculum* instead of the whole. For this purpose, I cut a speculum, three feet in focal length, through the centre, so as to divide it into two equal parts, and fitted up each part as a distinct telescope, so that I obtained two telescopes from one speculum. In this case, I found that each half of the speculum performed nearly as well as the whole speculum had done before; at least, there appeared to be *no very sensible* diminution in the *brightness* of the object, when viewed with a moderate power, and the image was equally accurate and distinct; so that if *economy* were a particular object aimed at in the construction of these instruments, two good telescopes might be obtained from one speculum; or if a speculum happened to be broken accidentally into large fragments, one or more of the fragments may be fitted up on this principle to serve as a tolerably good telescope.

From the experiments I have made in reference to these instruments, it is demonstrable that *a tube is not necessary* in the construction of a reflecting telescope—at least, on the principle now stated—whether it be used by day or by night, for terrestrial or celestial objects; for I have frequently used these telescopes in the open air in the daytime, without any inconvenience from extraneous light. Therefore, were a reflecting telescope of 50 or 60 feet in length to be constructed, it might be fitted up at a comparatively small expense, after the expense of the metallic substances, and of casting, grinding, and polishing the speculum is defrayed. The largest instrument of this description which has hitherto been constructed is the 40 feet reflector of Sir W. Herschel. This complicated and most unwieldy instrument had a tube of rolled or sheet iron 39 feet 4 inches in length, about 15 feet in circumference, and weighed about 8000 pounds. Now I conceive that such enormous tubes, in instruments of such dimensions, are altogether unnecessary. Nothing more is requisite than a short tube for holding the speculum. Connected with one side of this tube (or with both sides were it found necessary,) two strong bars of wood, projecting a few feet beyond the speculum end, and extending in front as far as the focal length of the mirror, and connected by crossbars of wood, iron, or brass, would be quite sufficient for a support to the eyepiece, and for directing the motion of the instrument. A telescope of 40 or 50 feet in length, constructed on this plan, would not require one-fifth of the expense, nor one-fourth of the apparatus and mechanical power for moving it to any required position, which were found necessary in the construction of Sir W. Herschel's large reflecting telescope. The idea here suggested will perhaps be more readily appreciated by an inspection of fig 71, where $A$ is the short tube, $B$ $C$ and $D$ $E$ the two large bars or arms, connected with crossbars, for the purpose of securing strength and steadi-

ness. At *I* and *K*, behind the speculum, weights might be applied, if necessary, for

Fig. 71.




counterbalancing the lever power of the long arm. *F* represents the position of the eyepiece, and *G H* the joint and part of the pedestal on which the instrument is placed. With regard to telescopes of smaller dimensions, as from 5 to 15 feet in focal length—with the exception of the expense of the specula and eyepieces—they might be fitted up for a sum not greater than from 8 to 10 or 15 guineas.

Were any person to attempt the construction of those telescopes, it is possible he might not succeed in his first attempts without more minute directions than I have yet given. The following directions may perhaps tend to guide the experimenter in adjusting the eyetube to the speculum, which is a point that requires to be particularly attended to, and on which depends the accurate performance of the instrument. After having fixed the eyepiece nearly in the position it should occupy, and directed the instrument to a particular object, look along the arm of the telescope, from *K* (fig. 69) to the extremity of the eyepiece at *H*, and observe whether it nearly coincides with the object. If the object appear lower than this line of vision, the eyepiece must be lowered, and if higher, it must be raised, by means of the nuts and screws at *g d* and *f e*, till the object and the line of vision now stated nearly coincide. The eyepiece should be directed as nearly perpendicular to the front of the speculum as possible, but so that the reflected image of one's head from the mirror shall not interfere to obstruct the rays from the object. An object may be seen with an approximate degree of distinctness, but not accurately, unless this adjustment be pretty accurately made. The astronomical eyepieces used for these telescopes are fitted with a brass cap, which slides on the end next the eye, and is capable of being brought nearer to or further from the first eyeglass. In the centre of this cap, next the eye, is a small hole, about the $\frac{1}{15}$th or $\frac{1}{10}$th of an inch diameter, or about as wide as to admit the point of a pin or a moderate-sized needle. The distance of this hole from the lens next the eye must be adjusted by trial, till the whole field of view appear distinct. A common astronomical eyepiece, without this addition, does not answer well. I find, by experience, that terrestrial eyepieces, such as those used in good achromatic telescopes, are, on the whole, best adapted to this construction of a reflecting telescope.

I have sometimes used these instruments for the purpose of viewing perspective prints, which they exhibit in a beautiful and interesting manner. If a coloured perspective be placed at one end of a large room or gallery, and strongly illuminated either by the sun or by two candles, and one of the reflectors, furnished with a small *magnifying power*, placed at the opposite end of the room, the representation of a street or a landscape will be seen in its true perspective, and will appear even more pleasant and interesting than when viewed through the common *optical diagonal machine*. If an inverting eyepiece be used—which is most eligible in this experiment—the print, of course, must be placed in an inverted position.

That reflecting telescopes of the descriptions now stated are original in their construction, appears from the uniform language of optical writers, some of whom have pronounced such attempts to be altogether impracticable. Sir David Brewster, one of the latest and most respectable writers on this subject, in the "Edinburgh Encyclopedia," art. *Optics*, and in the last edition of his *Appendix* to "Ferguson's Lectures," has the following remarks: "If we could dispense with the use of the small specula in telescopes of moderate length, by inclining the great speculum, and using an oblique, and, consequently, a *distorted* reflection, as proposed first by Le Maire, we should consider the Newtonian telescope as perfect; and on a large scale, or when the instrument exceeds 20 feet, it has undoubtedly this character, as nothing can be more simple than to magnify, by a single eyeglass, the image formed by a single speculum. As the *front view is quite impracticable*, and, indeed, *has never been attempted* in instruments of a small size, it becomes of great practicable consequence to remove as much as possible the evils which arise from the use of a small speculum," &c.

The instruments now described have effectuated, in some degree, the desirable object alluded to by this distinguished philosopher, and the mode of construction is neither that of Sir W. Herschel's front view, nor does it coincide with that proposed by Le Maire, which appears to have been a mere hint that

was never realized in the construction of reflecting telescopes of a small size. The simplicity of the construction of these instruments, and the excellence of their performance, have been much admired by several scientific gentlemen and others to whom they have been exhibited. Prior to the description of them in the Edinburgh Philosophical Journal, they were exhibited in the Calton Hill Observatory, Edinburgh, in the presence of Professor Wallace and another gentleman, who compared their performance with that of an excellent Gregorian. As this instrument is distinguished from every other telescope in being used without a tube, it has been denominated "*The Aerial Reflector.*"

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### Section V.

### *Earl of Rosse's Reflecting Telescopes.*

This nobleman, unlike many of his compeers, has, for a considerable number of years past, devoted his attention to the pursuits of science, and particularly to the improvement of reflecting telescopes. He is evidently possessed of high mathematical attainments, combined with an uncommon degree of mechanical ingenuity. About 14 or 15 years ago, he engaged in various experiments with the view of counteracting the effects of the spherical aberration of the specula of reflecting telescopes, which imperfection, if it could be completely remedied, would render the reflecting telescope almost a perfect instrument, as it is not affected by the different refrangibility of the rays of light. His method, we believe, consisted in forming a large speculum of two or three separate pieces of metal, which were afterward accurately combined into one—a central part, which was surrounded by one or two rings ground on the same tool. When the images formed by the separate pieces were made exactly to coincide, the image of the object towards which the whole speculum was directed was then found to be as distinct as either image had been when separate; but, as the period referred to, a sufficient number of experiments had not been made to determine that his lordship had completely accomplished the object he intended.

Great interest, however, has of late been excited by the improvements which his lordship has made in the formation of specula. Sir W. Herschel never made public the means by which he succeeded in giving such gigantic developement to the reflecting telescope, and therefore the construction of a *large* reflector has been considered as a perilous adventure; but, according to a report of Dr. Robinson, of Armagh, to the Irish Academy, the Earl of Rosse has overcome the difficulties which have hitherto been met with, and carried to an extent which even Herschel himself did not venture to contemplate, the illuminating power of this telescope, along with a sharpness of definition little inferior to that of the achromatic; and it is scarcely possible, he observes, to preserve the necessary sobriety of language in speaking of the moon's appearance with this instrument, which Dr. Robinson believes to be the most powerful ever constructed. The difficulty of constructing large specula, and of imparting to them the requisite degree of polish, has hitherto been considered so great, that from eight to twelve inches diameter has been, in general, their utmost size; indeed, except with the greatest reluctance, London opticians would not accept of orders for specula of more than nine inches in diameter. It appears, however, that the Earl of Rosse has succeeded, by a peculiar method of moulding, in casting object-mirrors of true *speculum metal of three feet in diameter, and of a weight exceeding* 17 *cwt.* He is about to construct a telescope, the speculum of which is *six feet* in diameter, *fifty feet focal distance*, and of the weight of *four tons;* and from what he has already accomplished, it is not doubted that he possesses the power to carry his design into effect. These great masses of metal, which, in the hands of all others makers of specula, would have been as untractable as so much unannealed flint-glass, the Earl of Rosse has further succeeded in bringing to the highest degree of polish, and the utmost perfection of curvature, by means of machinery. The process is conducted under water, by which means those variations of temperature, so fatal to the finest specula hitherto attempted, are effectually guarded against. To convince Dr. Robinson of the efficacy of this machinery, the earl took the three-feet speculum out of its telescope, destroyed its polished surface, and placed it under the mechanical polisher. In six hours it was taken out with a perfect new surface as bright as the original. Under the old system of hand polishing, it might have required months, and even years, to effect this restoration. Even before achieving these extraordinary triumphs on the solid substance, his lordship had constructed a six-feet reflector by covering a curved surface of brass with squares of the true *speculum metal*, which gave an immense quantity of light, though subject to some irregularities, arising from the number of joinings necessary in such a mosaic work. Of the performance of his lordship's great telescope, mounted with this reflector, those who have seen it speak in terms of high admiration; but in reference to the smaller and more

perfect instrument, furnished with the solid three-feet speculum, the language of the Armagh astronomer assumes a tone of enthusiasm, and even of sublimity. By means of this exquisite instrument, Dr. Robinson and Sir J. South, in the intervals of a rather unfavourable night, saw several new stars, and corrected numerous errors of other observers. For example, the planet Uranus, supposed to possess a ring similar to that of Saturn, was found not to have any such appendage; and those nebulæ, hitherto regarded, from their apparently circular outline, as "coalescing systems," appeared, when tested by the three-feet speculum, to be very far indeed from presenting a globular appearance, numerous offshoots and appendages, invisible by other telescopes, appearing in all directions radiating from their edges. Such discoveries, which reflect great honour on the Earl of Rosse, will doubtless have great effect on the interests of astronomical science.*

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## Section VI.

### *Reflecting Telescopes with Glass Specula.*

After making a variety of experiments with aerial telescopes constructed of metallic specula of different focal lengths, I constructed a telescope on the same plan with a concave glass mirror. Having obtained a fragment of a very large convex mirror which happened accidentally to have been broken, I caused the convex side to be foliated or silverized, and found its focal length to be about 27 inches. This mirror, which was about five inches diameter, I placed in one of the aerial reflectors instead of the metallic speculum, and tried its effects with different terrestrial eyepieces. With a power of about 35 or 40 times, it gave a beautiful and splendid view of distant terrestrial objects, the quantity of light reflected from them being considerably greater than when a metallic speculum was used, and they appeared, on the whole, well defined. The only imperfection—as I had foreseen—consisted in a double image being formed of objects which were remarkably bright and white, such as a lighthouse whitened on the outside, and strongly illuminated by the sun. One of the images was bright, and the other faint. This was obviously owing to the two reflections from the two surfaces of the mirror—one from the convex silverized side, and the other from the concave side next the eye, which produced the faint image—which circumstance has been generally considered as a sufficient reason for rejecting the use of glass specula in telescopes. But, although very bright objects exhibited a double image, almost all the other objects in the terrestrial landscape appeared quite distinct and without any secondary image, so that a common observer could scarcely have noticed any imperfection. When the instrument, however, was directed to celestial objects, the secondary image was somewhat vivid, so that every object appeared double. Jupiter appeared with two bodies, at a little distance from each other, and his four satellites appeared increased to eight. The moon likewise appeared as a double orb, but the principal image was distinct and well defined. Such a telescope, therefore, was not well adapted for celestial observations, but might answer well enough for viewing terrestrial objects.

Considering that the injurious effects of the secondary image arose from the images reflected from the two surfaces being formed near the same point, and at nearly the same focal distance, I formed a plan for destroying the secondary image, or at least counteracting its effects, by forming the concavity of the mirror next the eye of a portion of a sphere *different* from that of the convex side which was silverized, and from which the principal image is formed; but, for a long time, I could find no opticians possessed of tools of a sufficient length of radii for accomplishing my design. At length a London working optician undertook to finish a glass speculum according to my directions, which were, that the convex surface of the mirror should be ground on a tool which would produce a focal distance by reflection of about four feet, and that the concave surface should have its focal distance at about three feet three inches, so that the secondary image might be formed at about nine inches within the focal distance of the silverized side, and not interfere to disturb the principal image; but, either from ignorance or inattention, the artist mistook the radius for the half radius of concavity, and the speculum turned out to be only 23 inches focal distance by reflection. This mirror was fitted up as a telescope on the aerial plan, and I found, as I expected, the secondary image completely destroyed. It produced a very beautiful and brilliant view of land objects, and even the brightest objects exhibited no double image. The mirror was nearly five inches in diameter, but the image was most accurately defined when the aperture was contracted to about three inches. It was fitted with a terrestrial eyepiece which produced a magnifying power of about 25 times. When directed to the moon, it gave a very distinct

* A particular account of the Earl of Rosse's fifty-feet reflector, which is now finished, is given in the *Appendix*.

and luminous view of that orb, without the least appearance of a secondary image; but as the focal distance of the speculum was scarcely half the length I had prescribed, I did not apply to it any high astronomical powers, as I find that these can only be applied with effect, in this construction, to a speculum of a considerable focal length. Happening to have at hand a convex lens ten feet focal length and four inches in diameter, the one side of which had been ground to a certain degree of concavity, I caused the convex side to be foliated, which produced a focus by reflection at 13½ inches distant. To this mirror I applied terrestrial powers of 15 and 24 with considerable distinctness. The power of 15 produced a very brilliant and distinct view of land objects. Had the mirror been at least three times the focal length, it would have formed an excellent telescope with the same aperture.

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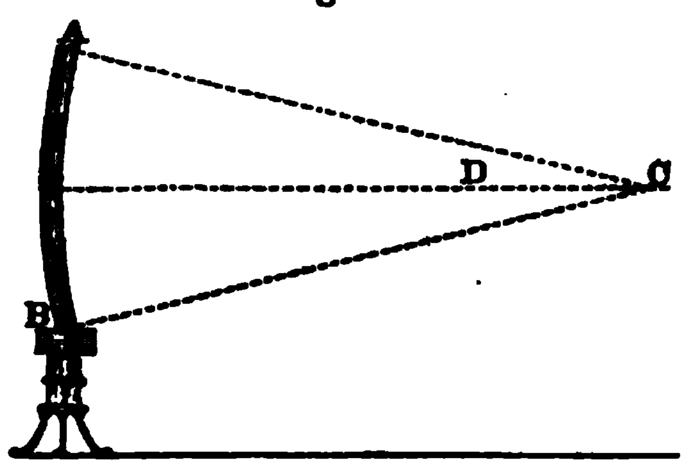
### Section VII.

### *A Reflecting Telescope, with a Single Mirror and no Eyepiece.*

On the same principle as that by which a refracting telescope may be constructed by means of a single lens, as represented fig. 51 (page 86,) we may form a telescope by reflection with a single mirror and without an eyepiece. Let *A B*, fig. 62, represent a large concave speculum, and *C* its focus: if an eye

Fig. 72.




be placed at *D*, about eight or ten inches within the focal point *C*, all the objects in the direction of *C*, or behind the spectator, will be seen magnified by reflection on the face of the mirror, and strongly illuminated. The magnifying power, in this case, will be nearly in the proportion of the focal length of the mirror to the focal length of the eye for near objects. If, for example, the focal distance of the mirror be eight feet, and the distance from the eye at which we see near objects most distinctly be eight inches, the magnifying power will be in the ratio of 8 to 96, or 12 times. I have a glass mirror of this description, whose focal length is four feet eight inches, and diameter six inches, which magnifies distant objects about seven times, takes in a large field of view, and exhibits objects with great brilliancy. It presents a very distinct picture of the moon, showing the different streaks of light and shade upon her surface, and in some cases shows the larger spots which traverse the solar disk. This mode of viewing objects is extremely easy and pleasant, especially when the mirror is of a large diameter, and the observer is at first struck and gratified with the novel aspect in which the objects appear.

Were a concave mirror of this description—whether of glass or of speculum metal—to be formed to a very long focus, the magnifying power would be considerable. One of 50 feet focal length, and of a corresponding diameter, might produce a magnifying power, to certain eyes, of about 75 times; and, from the quantity of light with which the object would be seen, its effect would be much greater than the same power applied to a common telescope. Sir W. Herschel states that, on one occasion, by looking with his naked eye on the speculum of his 40 feet reflector, without the interposition of any lens or mirror, he perceived distinctly one of the satellites of Saturn, which requires the application of a considerable power to be seen by an ordinary telescope. Such an instrument is one of the most simple forms of a telescope, and would exhibit a brilliant and interesting view of the moon, or of terrestrial objects.

PRICES OF REFLECTING TELESCOPES.

1. Prices as stated by Messrs. W. and S. Jones, Holborn, London.

| | £. | s. |
|---|---|---|
| A 4 feet, 7 inch aperture, Gregorian reflector, with the vertical motions upon a new invented principle, as well as apparatus to render the tube more steady for observation, according to the additional apparatus of small speculums, eyepieces, micrometers, &c. . *from* £80 to | 120 | 0 |
| 3 feet long, mounted on a plain brass stand . . . . . . | 23 | 2 |
| Ditto with rack-work motions, improved mountings and metals . | 39 | 18 |
| 2 feet long, without rack-work, and with 4 magnifying powers, improved . . . . . . | 15 | 15 |
| Ditto improved, with rack-work motions . . | 22 | 1 |
| 18 inch, on a plain stand . | 9 | 9 |
| 12 inch ditto . . . . . | 6 | 6 |

2. Prices as stated by Messrs. Tulley, Islington.

| | £. | s. |
|---|---|---|
| 1 foot Gregorian reflector, on pillar and claw stand, metal 2½ inches diameter, packed in a mahogany box | 6 | 6 |
| 1½ foot ditto, on pillar and claw stand, metal 3 inches diameter, packed in a mahogany box . | 11 | 11 |
| 2 feet ditto, metal 4 inches diameter | 16 | 16 |
| Ditto with rack-work motions . | 25 | 4 |
| 3 feet ditto, metal 5 inches diameter, rack-work motions . . | 42 | 0 |
| 4 feet ditto, metal 7 inches diameter, on a tripod stand with centre of gravity motion . . . . . | 105 | 0 |
| 6 feet ditto, metal 9 inches diameter . . . . . . | 210 | 0 |
| 7 feet *Newtonian*, 6 inches aperture . . . . . . . | 105 | 0 |
| 12 feet ditto, metal 12 inches diameter . . . . . . | 525 | 0 |

3. Prices as stated by Mr. G. Dollond, St. Paul's Churchyard.

| | £. | s. |
|---|---|---|
| Reflecting telescopes 14 inches long, in a mahogany box . . | 9 | 9 |
| Ditto 18 inches . . . | 12 | 12 |
| Ditto 2 feet . . . . | 18 | 18 |
| Ditto with 4 different powers, and rack-work stand supporting the telescope in the centre of gravity . | 36 | 15 |
| Ditto 3 feet, with ditto . . | 50 | 0 |

4. Prices of single speculums and reflecting telescopes, as made by Mr. Grub, Charlemont Bridge-works, Dublin.

| NEWTONIAN TELESCOPES. | | | | | |
|---|---|---|---|---|---|
| Diameter in inches. | Focal length in feet. | Price of mirrors alone. | | Price of telescope complete, without stand. | |
| | | £. | s. | £. | s. |
| 7 | 7 | 17 | 10 | 27 | 10 |
| 9 | 10 | 25 | 0 | 40 | 0 |
| 12 | 12 | 60 | 0 | 90 | 0 |
| 15 | 15 | 120 | 0 | 170 | 0 |
| 18 | 18 | 200 | 0 | 260 | 0 |

| GREGORIAN REFLECTORS. | | | | | |
|---|---|---|---|---|---|
| Diameter in inches. | Focal length in feet. | Price of mirrors alone. | | Price of telescope complete, without stand. | |
| | | £. | s. | £. | s. |
| 6 | 2 | 17 | 10 | 25 | 0 |
| 7 | 3 | 25 | 0 | 34 | 0 |
| 9 | 4½ | 35 | 0 | 50 | 0 |
| 12 | 7 | 70 | 0 | 100 | 0 |
| 15 | 9 | 150 | 0 | 200 | 0 |
| 18 | 12 | 240 | 0 | 300 | 0 |

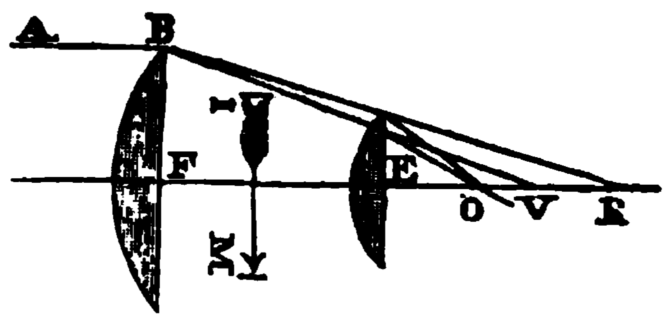
## ON THE EYEPIECES OF TELESCOPES.

Although the performance of telescopes chiefly depends on the goodness of the object-glass, or the object-speculum of the instrument, yet it is of considerable importance, in order to distinct vision, and to obtain a large and uniformly distinct field of view, that the eyepiece be properly constructed. The different kinds of eyepieces may be arranged into two general divisions, *Astronomical* and *Terrestrial*.

1. *Astronomical Eyepieces.*—The most simple astronomical eyepiece is that which consists of a single convex lens; and when the focal distance of this lens, and that of the object-glass of the instrument, is accurately ascertained, the magnifying power may be nicely determined by dividing the focal length of the object-lens by that of the eyeglass; but as the pencil of white light transmitted by the object-glass will be divided by the eyeglass into its component colours, the object will appear bordered with coloured fringes, and the distinctness of vision consequently injured; besides, the spherical aberration, when a single lens is used, is much greater than when two or more glasses are employed: hence astronomical eyepieces are now formed by a combination of at least two lenses.

The combination of lenses now generally used for astronomical purposes is that which is usually denominated the *Huygenian Eyepiece*, having been first proposed by the celebrated Huygens as a great improvement on the single lens eyepiece. The following figure (73) represents a section of this eyepiece:

Fig. 73.



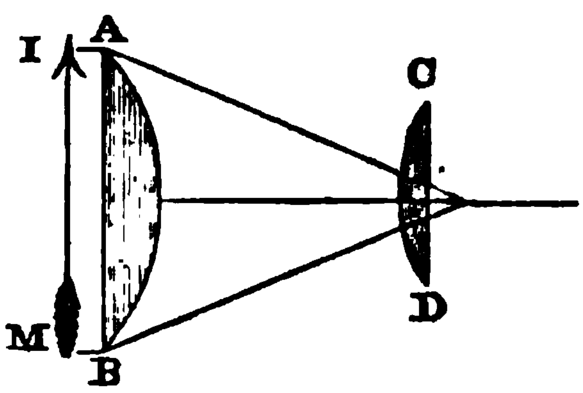

Let *A B* be a compounded pencil of white light proceeding from the object-glass; *B F* a plano-convex field-glass, with its plane side next the eyeglass *E*. The red rays of the pencil *A B*, after refraction, would cross the axis in *R*, and the violet rays in *V*; but, meeting the eyeglass *E*, the red rays will be refracted to *O*, and the violet nearly in the same direction, when they will cross each other about the point *O* in the axis, and unite. The distance of the two glasses *F E*, to produce this correction, when made of crown glass, must be equal to half the sum of their

focal distances nearly: for example, suppose the focal distance of the largest, or field-lens, to be three inches, and the focal distance of the lens next the eye one inch, the two lenses should be placed exactly at the distance of two inches, the sum of their focal length being four, the half of which is two. In other words, the glass next the eye should be placed as much *within* the focus of the field-glass as is equal to its own focal distance. The focal length of a single lens that has the same magnifying power as this compound eyepiece, is equal to twice the product of the focal lengths of the two lenses divided by the sum of the same numbers; or, it is equal to half the focal length of the field-glass. Thus, in reference to the preceding example, twice the product of the focal length of the two lenses is equal to six, and their sum is four. The former number divided by the latter produces a quotient of 1½, which is the focal length of a single lens, which would produce the same magnifying power as the eyepiece; and 1½ is just half the focal length of the field-glass. The proportion of the focal lengths of the two lenses to each other, according to Huygens, should be as three to one; that is, if the field-glass be 4½ inches, the eyeglass should be 1½, and this is the proportion most generally adopted; but some opticians have recommended that the proportion should be as three to two. Boscovich recommended two similar lenses; and in this case the distance between them was equal to half the sum of their focal distances, as in the Huygenian eyepiece.

The image is formed at *I M*, at the focal distance of the lens next the eye, and at the same distance from the field-glass. When distinct vision is the principal object of an achromatic telescope, the two lenses are usually both plano-convex, and fixed with their curved faces towards the object-glass, as in the figure. Sometimes, however, they consist of what is called *crossed* lenses, that is, lenses ground on one side to a short focus, and on the other side to a pretty long focus, the sides with the deepest curves being turned towards the object-glass. A diaphragm, or aperture of a proper diameter, is placed at the focus of the eye-lens where the image formed by the object-glass falls, for the purpose of cutting off the extreme rays of the field-lens, and rendering every part of the field of view equally distinct. This is likewise the form of the eyepiece generally applied to Gregorian reflectors. In short, when accurately constructed, it is applicable to telescopes of every description. This eyepiece, having the image viewed by the eye behind the inner lens, is generally called the *negative* eyepiece, and is that which the optical instrument makers usually supply, of three or four different sizes, for so many magnifying powers, to be applied to different celestial objects, according to their nature, or the state of the atmosphere in which they are used.

*Ramsden's Eyepiece.*—There is another modification of lenses, known by the name of the *Positive*, or Ramsden's Eyepiece, which is much used in transit instruments, and telescopes which are furnished with micrometers, and which affords equally good vision as the other eyepiece. In this construction the lenses are plano-convex, and nearly of the same focus, but are placed at a distance from each other less than the focal distance of the glass next the eye, so that the image of the object viewed is beyond both the lenses when measuring from the eye. The flat faces of the two lenses are turned into contrary directions in this eyepiece, one facing the object-glass, and the other the eye of the observer; and as the image formed at the focus of the object-glass lies parallel to the flat face of the contiguous lens, every part of the field of view is distinct at the same adjustment, or, as opticians say, there is a *flat field*, which, without a diaphragm, prevents distortion of the object. This eyepiece is represented in fig. 74, where *A B*

Fig. 74.

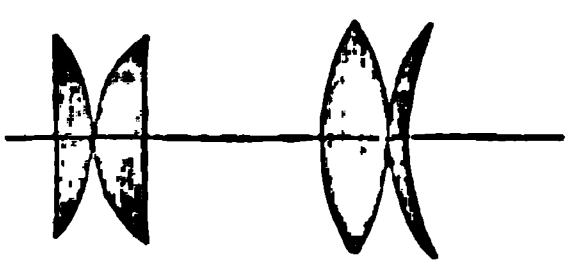



and *C D* are two plano-convex lenses, with their convex sides inward. They have nearly the some focal length, and are placed at a distance from each other equal to about two-thirds of the focal length of either. The focal length to an equivalent single lens is equal to three-fourths the focal length of either lens, supposing them to have equal focal distances. This eyepiece is generally applied when wires of spider's lines are used in the common focus. as the piece containing the lenses can be taken out without disturbing the lines, and is adjustable for distinct vision; and whatever may be the measure of any object given by the wire micrometer at the solar focus, it is not altered by a change of the magnifying power when a second eyepiece of this construction is substituted.

*Aberration of Lenses.*—In connexion with the above descriptions, the following statements respecting the spherical aberration of lenses may not be inappropriate. Mr. John Dollond, in a letter to Mr. Short, remarks, that

"the aberration in a single lens is as the cube of the refracted angle; but if the refraction be caused by two lenses, the sum of the cubes of each half will be a quarter of the refracted angle, twice the cube of one being a quarter of the cube of two. So three times the cube of one is only *one-ninth* of the cube of three," &c. Hence the indistinctness of the borders of the field of view of a telescope is diminished by increasing the number of lenses in an eyepiece. Sir J. Herschel has shown that if two plano-convex lenses are put together as in fig. 75, the aberration will be only 0.2481, or *one-fourth* of that of a single lens in its best form. The focal length of the first of these lenses must be to that of the second as 1 to $\frac{2}{3}$. If their focal lengths are equal, the aberration will be 0.603, or nearly one-half. The spherical aberration, however, may be *entirely* destroyed by combining a meniscus and double convex lens, as shown in fig. 76,

Fig. 75. Fig. 76.



the convex sides being turned to the eye when they are used as lenses, and to parallel rays when they are used as burning glasses. Sir J. Herschel has computed the following curvatures for such lenses:

| | |
|---|---|
| *Focal length of the convex lens* . | +10.000 |
| Radius of its first surface . . | + 5.833 |
| Radius of its second surface . | —35.000 |
| *Focal length of the meniscus* . | +17.829 |
| Radius of its first surface . . | + 3.688 |
| Radius of its second surface . | + 6.294 |
| Focal length of the compound lens | + 6.407 |

On the general principles above stated, a good astronomical eyepiece may be easily constructed with two proper lenses, either according to the plan of Huygens or that of Ramsden: and, from what has been now stated, it is demonstrably certain that, in all cases where two glasses are properly combined, such an eyepiece is superior to a single lens both in point of distinctness and of the enlargement of the field of view. I lately fitted up an eyepiece, on Ramsden's principle, with two lenses, each about three inches focal length, and $1\frac{3}{8}$ths of an inch in diameter, placed at half an inch distant, with their convex surface facing each other, as in fig. 74, which forms an excellent eyepiece for an achromatic telescope six feet eight inches focal distance and four inches aperture, particularly for viewing clusters of stars, the Milky Way, and the large nebulæ. The field of view is large, the magnifying power is only between 50 and 60 times, and the quantity of light being so great, every celestial object appears with great brilliancy, and it is, in general, much more preferable, when applied to the stars, than any of the higher powers. When applied to *Præsepe* in Cancer, it exhibits that group at one view, as consisting of nearly 100 stars, which exhibit a beautiful and most striking appearance.

It may appear a curious circumstance that any eyepiece which is good with a short telescope is also good with a long one, but that the reverse is not true; for it is found to be more difficult to make a good eyepiece for a short than for a long focal distance of the object-glass.

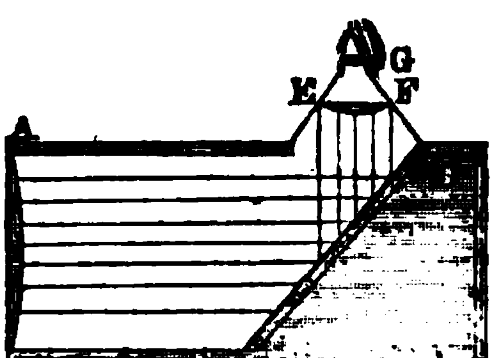
Celestial eyepieces are sometimes constructed so as to produce *variable powers*. This is effected by giving a motion to the lens next the eye, so as to remove it nearer to or further from the field-lens; for at every different distance at which it is placed from the other lens, the magnifying power will either be increased or diminished. The greatest power is when the two lenses are nearly in contact, and the power diminishes in proportion to the distance at which the glass next the eye is removed from the other. The scale of distance, however, between the two lenses cannot be greater than the focal distance of the field, or inner glass; for if it were, the lenses would no longer form an eyepiece, but would be changed into an inverting opera-glass. For effecting the purpose now stated, the eyeglass is fixed in a tube, which slides upon an interior tube, on which is marked a scale of distances corresponding to certain magnifying powers; and in this way an eyepiece may be made to magnify about double the number of times when the lenses are in one position than when they are in another; as, for example, all the powers from 36 to 72 times may be thus applied, merely by regulating the distance between the two lenses. When the glasses are varied in this manner, the eyepiece becomes sometimes a *positive* eyepiece, like Ramsden's, and sometimes a negative one, like that of Huygens.

*Diagonal Eyepieces.*—The eyepieces to which we have now adverted, when adapted to refracting telescopes, both reverse and invert the object, and therefore are not calculated for showing terrestrial objects in their natural position; but as the heavenly bodies are of a spherical form, this circumstance detracts nothing from their utility. When the celestial object, however, is at a high altitude, the observer is obliged to place his head in a very inconvenient position, and to direct his eye nearly upward; in which position he can-

not remain long at ease, or observe with a steady eye. To remedy this inconvenience, the diagonal eyepiece has been inverted, which admits of the eye being applied at the side, or at the upper part of the eyepiece, instead of the end; and when such an eyepiece is used, it is of no importance in what direction the telescope is elevated, as the observer can then either sit or stand erect, and look down upon the object with the utmost ease. This object is effected by placing a flat piece of polished speculum-metal at an angle of 45 degrees in respect to the two lenses of the eyepiece, which alters the direction of the converging rays, and forms an image which becomes erect with respect to altitude, but is reversed with respect to azimuth; that is, in other words, when we look down upon the objects in the field of view, they appear erect; but that part of an object which is in reality on our right hand, appears on our left; and if it be in motion, its *apparent* is opposite to its *real* motion; if it be moving towards the west, it will seem to move towards the east.

There are three situations in which the diagonal reflector in this eyepeice may be placed. It may be placed either, 1, before the eyepiece, or, 2, behind it, or, 3, between the two lenses of which the eyepiece consists. The most common position of the reflector is between the lenses; and this may be done both in the negative and the positive eyepieces; but as the distance between the two lenses is necessarily considerable to make room for the diagonal position of the reflector, the magnifying power cannot be great; otherwise a diagonal eyepiece of this construction remains always in adjustment, and is useful in all cases where a high power is not required. The preceding is a description and representation of a diagonal eyepiece of this kind in my possession.

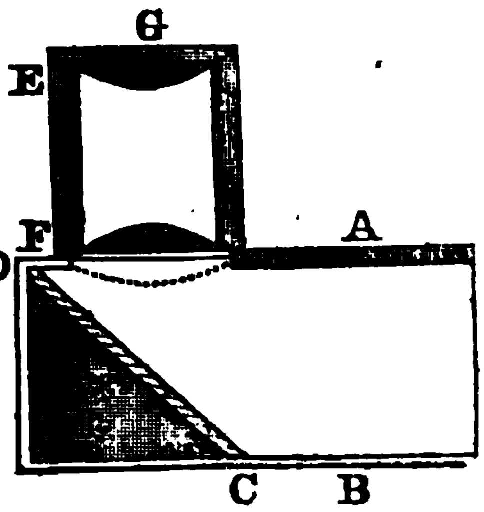
Fig. 77




In fig. 77, *A B* represents the plano-convex lens next the object, which is about 2 inches in focal length, and ¾ of an inch in diameter; *C D*, a plain metallic speculum of an oval form, well polished, and placed at half a right angle to the axis of the tube; and *E F* another plano-convex lens, about 1½ inch focal distance. The centre of the speculum is about 1¼th of an inch from the lens *A B*, and about half or one-third of an inch from *E F*; so that this eyepiece is a *positive* one, on the principle proposed by Ramsden. The rays proceeding from the lens *A B*, and falling upon the speculum, are reflected in a perpendicular direction to the lens *E F*, where they enter the eye at *G*, which looks down upon the object through the side of the tube. The real size of this eyepiece is much about the same as that represented in the figure. When applied to an achromatic telescope of 44½ inches focal distance, it produces a magnifying power of 36 times, and exhibits a very beautiful view of the whole of the full moon. It likewise presents a very pleasing prospect of terrestrial objects, which appear as if situated immediately below us.

Another plan of the diagonal eyepiece is represented in fig. 78, where the speculum is fixed *within* the sliding tube which receives the eyepiece, or immediately below it. The part of the tube *A B* slides into the tube of the telescope, *C D* is the speculum placed at half a right angle to the axis of the tube, and *E F* the tube containing the lenses, which stands at right angles to the position of the telescope, and slides into an exterior tube, and the eye is applied at *G*.

Fig. 78.




This construction of the diagonal eyepiece may be used with any eyepiece whatever, whether the Huygenian or that of Ramsden. It will admit of any magnifying power, and if several different eyepieces be fitted to the sliding tube, they may be changed at pleasure. This form of the diagonal eyepiece I therefore consider as the best and the most convenient construction, although it is not commonly adopted by opticians.

When any of these eyepieces are applied to a telescope, with the lens *E* on the upper part of it, we look down upon the object, if it be a terrestrial one, as if it were under our feet. If we turn the eyepiece round in its socket a quarter of a circle towards the left, an object directly before us in the south will appear as if it were in the *west*, and turned upside down. If, from this position, it is turned round a semicircle towards the right, and the eye applied, the same object will appear as if it were situated in the east, and inverted; and if it be turned round another quadrant, till it be directly opposite to its first position, and the eye applied from below, the object or landscape will appear as if suspended in the atmosphere above us. This eyepiece, therefore, is capable of exhibiting objects in a

great variety of aspects, and the use of it is both pleasant and easy for the observer. But there is a considerable loss of light, occasioned by the reflection from the speculum, which is sensibly felt when very high powers are applied; and therefore, when very small stars are to be observed, such as some of those connected with double or triple stars, the observer should not study his own ease so much as the quantity of light he can retain with a high power, which object is best attained with an ordinary eyepiece and a telescope of large aperture.

We have said that a diagonal eyepiece may be constructed with a reflector *before* the eyepiece. In this case, the speculum is sometimes made to slide before the eye at the requisite angle of reclination, in which application each eyepiece must necessarily have a groove to receive it, and the eye must be applied without a hole to direct it, but it may be put on and taken off without disturbing the adjustment for distinct vision, and is very simple in its application. But, on the whole, the form represented in fig. 78 is the most convenient, and should generally be preferred, as any common astronomical eyepiece can be applied to it. I have used a diagonal eyepiece of this kind with good effect when a power of 180 has been applied to the sun and other celestial objects.

Instead of a metallic speculum, a *rectangular prism of glass*, is sometimes substituted; for the rays of light are then bent by reflection from the second polished surface, which ought to be *dry*, and undergo two refractions, which achromatize them; and the same effect is thus produced as by polished metal. Ramsden sometimes gave one of the polished faces of a right-angled prism a curve, which prism served instead of a lens in an eyepiece, and also performed the office of a reflector. A semi-globe, or what has been called a bull's eye, has also been used as a diagonal eyepiece, and when the curve is well formed, and the glass good, it is achromatic, and is said to perform pretty well, but it is not superior to the forms already described.

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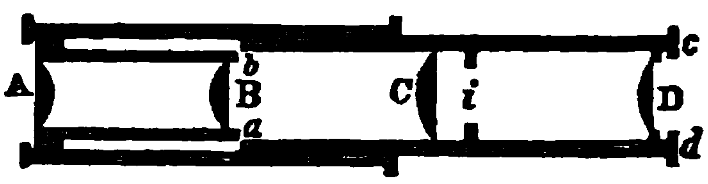
## Section II.

### *Terrestrial Eyepieces.*

When describing the common refracting telescope (p. 84,) I have noticed that three eyeglasses, placed at double their focal distances from each other, formerly constituted the terrestrial eyepiece, as represented in fig. 47. But this construction, especially for achromatic instruments, has now become obsolete, and is never used except in small pocket spyglasses formed with a single object-lens. In its place a four glassed eyepiece has been substituted, which is now universally used in all good telescopes, and which, besides improving the vision and producing an erect position of the images of objects, presents a considerably larger field of view. During the progressive stages of improvement made in the construction of erect eyepieces by Dollond and Ramsden, three, four, and five lenses were successively introduced; and hence, in some of the old telescopes constructed by these artists, we frequently find five lenses of different descriptions composing the eyepiece. But four lenses, arranged in the manner I am now about to describe, have ultimately obtained the preference. In a telescope having a celestial eyepiece of the Huygenian form, the image that is formed in the focus of the object-glass is that which is seen magnified, and in an inverted position; but when a four glassed eyepiece is used, which produces an erect view of the object, the image is repeated, and the *second* image, which is formed by the inner pair of lenses, *A B*, on an enlarged scale, is that which the pair of lenses, *C D*, at the eye end render visible on a scale still more enlarged. The modern terrestrial eyepiece, represented in fig. 79, is,

Fig 79.




in fact, nothing else than a compound microscope, consisting of an object-lens, an amplifying-lens, and an eyepiece composed of a pair of lenses on the principle of the Huygenian eyepiece. Its properties will be best understood by considering the first image of an object, which is formed in the focus of the object-glass, as a small luminous object to be rendered visible, in a magnified state, by a compound microscope. The object to be magnified may be considered as placed near the point *A*, and the magnified image at *i*, which is viewed by the lens *D*. Hence, if we look through such an eyepiece at a small object placed very near the lens *A*, we shall find that it acts as a compound microscope of a moderate magnifying power, increasing, in some cases, the diameter of the object about 10 times, and 100 times in surface.

In order to distinguish the different lenses in this eyepiece, we may call the lens *A* which is next to the first image, the *object-lens;* the next to it, *B*, the the *amplifying-lens;* the third, or *C*, the *field-lens;* and the

one next the eye, $D$, the *eye-lens*. The first image, formed a little before $A$, may be denominated the *radiant*, or the object from which the rays proceed. Now it is well known as a principle in optics, that if the radiant be brought nearer to the lens than its principal focus, the emerging rays will *diverge*, and, on the contrary, if the radiant be put further from the lens than its principal focal distance, the emerging rays will *converge* to a point at a distance beyond the lens, which will depend on the distance of the radiant from the face of the lens. In this place an image of the radiant will be formed by the concurrence of the converging rays, but in a contrary position; and the length of the image will exceed the length of the radiant in the same proportion, as the distance of the image from the radiant exceeds that of the radiant from the lens. This secondary image of the radiant at $i$, is not well defined when only one lens, as $A$, is used, owing to the great spherical aberrations, and therefore the amplifying lens is placed at the distance of the shorter conjugate focus, with an intervening diaphragm of a small diameter at the place of the principal focus; the uses of which lens and diaphragm are, first, to cut off the coloured rays that are occasioned by the dispersive property of the object-lens, and, secondly, to bring the rays to a shorter conjugate focus for the place of the image than would have taken place with a single lens having only one refraction. As the secondary image is in this way much better defined and free from coloration, the addition of this second lens is a great improvement to vision For this reason, I am clearly of opinion that the object-glass of a compound microscope, instead of consisting of a small single lens, should be formed of two lenses on the principle now stated, which would unquestionably add to the distinctness of vision.

With respect to *the proportions of the focal lengths of the lenses* in this four glass eyepiece, Mr. Coddington states, that if the focal lengths, reckoning from $A$ to $D$, fig. 79, be as the numbers 3, 4, 4, and 3, and the distances between them on the same scale, 4, 6, and 5, 2, the radii, reckoning from the outer surface of $A$, should be thus:

| | | | |
|---|---|---|---|
| $A$ | First surface | 27 | nearly plano-convex. |
| | Second surface | 1 | |
| $B$ | First surface | 9 | a meniscus. |
| | Second surface | 4 | |
| $C$ | First surface | 1 | nearly plano-convex. |
| | Second surface | 21 | |
| $D$ | First surface | 1 | double convex. |
| | Second surface | 24 | |

Sir D. Brewster states that a good achromatic eyepiece may be made of four lenses, if their focal lengths, reckoning from that next the object, be as the numbers 14, 21, 27, 32; their distances, 23, 44, 40; their apertures, 5.6, 3.4, 2.6; and the aperture of the diaphragm placed in the interior focus of the fourth eyeglass, 7. Another proportion may be stated: Suppose the lens next the object, $A$, to be $1\frac{7}{8}$ths of an inch focal length, then $B$ may be $2\frac{1}{2}$ inches; $C$, 2 inches; and $D$, $1\frac{1}{2}$; and their distances, $A$ $B$, $2\frac{1}{2}$; $B$ $C$, $3\frac{3}{8}$ths; and $C$ $D$, $2\frac{3}{8}$ths. In one of Ramsden's small telescopes, whose object-glass was $8\frac{1}{2}$ inches in focal length, and its magnifying power 15.4, the focal lengths of the eyeglasses were, $A$, 0.775 of an inch; $B$, 1.025; $C$, 1.01; $D$, 0.79; the distances, $A$ $B$, 1.18; $B$ $C$, 1.83; and $C$ $D$, 1.105. In the excellent achromatic telescope of Dollond's construction which belonged to the Duc de Chaulnes, the focal lengths of the eyeglasses, beginning with that next the object, were $14\frac{1}{4}$ lines, 19, $22\frac{3}{4}$, 14; their distances, 22.48 lines, 46.17, 21.45; and their thickness at the centre, 1.23 lines, 1.25, 1.47. The fourth lens was plano-convex, with the plane side to the eye, and the rest were double convex lenses. This telescope was in focal length three feet five and a half inches.

The magnifying power of this eyepiece, as usually made, differs only in a small degree from what would be produced by using the first or the fourth glass alone, in which case the magnifying power would be somewhat greater, but the vision less distinct; and were the lens next the eye used alone without the field-glass, the field of view would be much contracted. Stops should be placed between the lenses $A$ and $B$, near to $B$, and a larger one between $C$ and $D$, to prevent any false light from passing through the lenses to the eye. The more stops that are introduced into a telescope—which should all be blackened—provided they do not hinder the pencils of light proceeding from the object, the better will the instrument perform.

For the information of amateur constructors of telescopes, I shall here state the dimensions of two or three four glassed eyepieces in my possession, which perform with great distinctness, and present a pretty large field of view. In one of these, adapted to a $44\frac{1}{2}$ inch achromatic, the lens, $A$, next the object, is $1\frac{7}{8}$ths of an inch focal length and about one inch in diameter, with the plane side next the object. The focal length of the lens $B$, $2\frac{1}{10}$th inches, diameter $\frac{7}{10}$ths of an inch, with its plane side next $A$; distance of these lenses from each other, $2\frac{4}{10}$th inches; distance of the field-lens $C$ from the lens $B$, $5\frac{1}{2}$ inches. The small hole or diaphragm between $A$ and $B$ is at the focus of $A$, and is about one-sixth of an inch in diameter, and about three-eighths

of an inch from the lens *B*. The field-lens *C* is two inches focal length, and $1\frac{1}{4}$th of an inch in diameter, with its plane side next the eye. The lens next the eye, *D*, is one inch focal distance, half an inch in diameter, and is distant from the field-glass $1\frac{3}{4}$ths of an inch, with its plane side next the eye. The magnifying power of this eyepiece is equivalent to that of a single lens whose focal length is half an inch, and with the $44\frac{1}{2}$ inch object-glass produces a power of about 90 times. The lens next the eye can be changed for another of $1\frac{3}{8}$ths of an inch focal length, which produces a power of 65, and the two glasses *C D* can be changed for another set of a longer focal distance, which produces a power of 45 times. The whole length of this eyepiece is $11\frac{1}{2}$ inches.

In another eyepiece, adapted to a pocket achromatic, whose object-glass is nine inches focal length, the lens *A* is one inch focal length and half an inch in diameter; the lens *B*, $1\frac{1}{4}$th of an inch, and half an inch in diameter; their distance, $1\frac{1}{2}$ inches; the lens *C*, $1\frac{1}{10}$th of an inch focal length and five-eighths of an inch in diameter; the eyelens *D*, five-eighths of an inch focal length and three-eighths of an inch in diameter; distance between *C* and *D*, $1\frac{1}{8}$th of an inch; the distance between *B* and *C*, $1\frac{3}{4}$ths of an inch. The whole length of this eyepiece is $4\frac{1}{2}$ inches, and its power is nearly equal to that of a single lens of half or $\frac{6}{10}$ths of an inch focal length, the magnifying power of the telescope being about 16 times. Another eyepiece of much larger dimensions has the lens *A* of $2\frac{1}{2}$ inches focal length and three-fourths of an inch in diameter; the lens *B*, $2\frac{3}{4}$th inches focus and five-eighths of an inch in diameter, and their distance $2\frac{3}{4}$th inches; the lens *C*, $2\frac{3}{8}$th inches focus and $1\frac{1}{8}$th of an inch in diameter: the lens *D*, $1\frac{3}{4}$ths of an inch focus and three-fourths of an inch in diameter; distance from each other, $2\frac{3}{4}$th inches. The distance between the lenses *B* and *C* is four inches. The magnifying power is equal to that of a single lens $1\frac{1}{8}$th of an inch focal distance. When applied to an achromatic object-glass six feet seven inches focal length, it produces a power of about 70 times. This eyepiece has a movable tube nine inches in length, in which the two lenses next the eye are contained, by pulling out which, and consequently increasing the distance between the lenses *B* and *C*, the magnifying power may be increased to 100, 120, or 140, according to the distance to which this movable tube is drawn out. It has also a second and third set of lenses, corresponding to *C* and *D*, of a shorter focal distance, which produce higher magnifying powers on a principle to be afterwards explained.

*Description of an Eyepiece, &c., of an old Dutch Achromatic Telescope.*

About twenty or thirty years ago, I purchased, in an optician's shop in Edinburgh, a small achromatic telescope, made in Amsterdam, which was supposed by the optician to have been constructed prior to the invention of achromatic telescopes by Mr. Dollond. It is mounted wholly of brass, and in all its parts is a piece of beautiful and exquisite workmanship, and the utmost care seems to have been taken to have all the glasses and diaphragms accurately adjusted. The object-glass is a double achromatic, $6\frac{1}{2}$ inches focal distance and one inch in diameter, but the clear aperture is only seven-eighths of an inch in diameter. It is perfectly achromatic, and would bear a power of 50 times if it had a sufficient quantity of light. The following inscription is engraved on the tube adjacent to the object-glass: "*Jan van Deyl en Zoon, Invenit et Fecit, Amsterdam, Ao.* 1769." Although Dollond exhibited the principle of an achromatic eight or ten years before the date here specified, yet it is not improbable that the artist whose name is here stated may not have heard of Dollond's invention, and that he was really, as he assumes, one of the inventors of the achromatic telescope; for the invention of this telescope by Dollond was not very generally known, except among philosophers and the London opticians, till a number of years after the date above stated. Euler, in his "Letters to a German Princess," in which telescopes are particularly described, makes no mention of, nor the least allusion to, the invention of Dollond, though this was a subject which particularly engaged his attention. Now these letters were written in 1762, but were not published till 1770. When alluding to the defects in telescopes arising from the different refrangibility of the rays of light, in Letter 43, and that they might possibly be rectified by means of different transparent substances, he says, "But neither theory nor practice have hitherto been carried to the degree of perfection necessary to the execution of a structure which should remedy these defects." Mr. B. Martin, in his "Gentleman and Lady's Philosophy," published in 1781, alludes to the achromatic telescope, but speaks of it as if it were but very little, if at all, superior to the common refracting telescope: and therefore I think it highly probable that Jan van Deyl was really an inventor of an achromatic telescope before he had any notice of what Dollond and others had done in this way some short time before.

But my principal object in adverting to this telescope is to describe the structure of the eyepiece, which is a very fine one, and which

is somewhat different from the achromatic eyepiece above described. It consists of four glasses, two combined next the eye, and two next the object. Each of these combinations forms an astronomical eyepiece nearly similar to the Huygenian. The lens *A*, next the object, fig. 80, is five-eighths of an inch focal

Fig. 80.


distance, and $\frac{4}{10}$ths of an inch in diameter; the lens *B*, three-eighths of an inch focus, and one-fifth of an inch in diameter, and the distance between them somewhat less than five-eighths of an inch; the diameter of the aperture *e* about $\frac{1}{15}$th of an inch. This combination forms an excellent astronomical eyepiece, with a large flat field, and its magnifying power is equivalent to that of a single lens five-eighths or six-eighths of an inch focal length. The lens *C* is half an inch focal length, and $\frac{4}{10}$ths of an inch in diameter; the lens *D* a quarter of an inch focus, and about one-fifth of an inch in diameter; their distance about half an inch, or a small fraction more. The hole at *d* is about $\frac{1}{20}$th or $\frac{1}{25}$th of an inch in diameter, and the distance between the lenses *B* and *C* about 1½ inches. The whole length of the eyepiece is 3¼th inches—exactly the same size as represented in the engraving. Its magnifying power is equal to that of a single lens one-fourth of an inch focal length; and consequently the telescope, though only 9½ inches long, magnifies twenty-six times with great distinctness, though there is a little deficiency of light when viewing land objects which are not well illuminated.

The glasses of this telescope are all plano-convex, with their convex sides towards the object, except the lens *D*, which is double convex, but flattest on the side next the eye, and they are all very accurately finished. The two lenses *C* and *D* form an astronomical eyepiece nearly similar to that formed by the lenses *A* and *B*. The focus of the telescope is adjusted by a screw, the threads of which are formed upon the outside of a tube into which the eyepiece slides. The eyepiece and apparatus connected with it is screwed into the inside of the main tube when not in use, when the instrument forms a compact brass cylinder six inches long, which is inclosed in a fish-skin case, lined with silk velvet, which opens with hinges.

The lenses in the eyepieces formerly described, though stated to be plano-convexes, are, for the most part, *crossed glasses*, that is, ground on tools of a long focus on the one side, and to a short focus on the other. The construction of the eyepiece of the Dutch telescope above described is one which might be adopted with a good effect in most of our achromatic telescopes; and I am persuaded, from the application I have made of it to various telescopes, that it is even superior in distinctness and accuracy, and in the *flatness of field* which it produces, to the eyepiece in common use. The two astronomical eyepieces of which it consists, when applied to large achromatic telescopes, perform with great accuracy, and are excellently adapted for celestial observations.

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SECTION III.

*Description of the Pancratic Eyetube.*

From what we have stated when describing the common terrestrial eyepiece now applied to achromatic instruments (p. 124, fig. 79,) it appears obvious that any variety of magnifying powers, within certain limits, may be obtained by removing the set of lenses *C D*, fig. 79, nearer to or further from the tube which contains the lenses *A* and *B*, on the same principle as the magnifying power of a compound microscope is increased by removing the eyeglasses to a greater distance from the object-lens. If, then, the pair of eyelenses *C D* be attached to an inner tube that will draw out and increase their distance from the inner pair of lenses, as the tube *a b c d*, the magnifying power may be indefinitely increased or diminished by pushing in or drawing out the sliding tube, and a scale might be placed on this tube, which, if divided into equal intervals, will be a scale of magnifying powers, by which the power of the telescope will be seen at every division, when the lowest power is once determined.

Sir David Brewster, in his "Treatise on New Philosophical Instruments," Book I. chap. vii. page 59, published in 1813, has adverted to this circumstance in his description of an "Eyepiece Wire Micrometer," and complains of Mr. Ezekiel Walker having in the "Philosophical Magazine" for August, 1811, described such an instrument as an invention of his own. Dr. Kitchener some years afterward described what he called a Pancratic or omnipotent eyepiece, and got one made by Dollond, with a few modifications different from that suggested by Brewster and Walker, which were little else than cutting

the single tube into several parts, and giving it the *appearance* of a new invention. In fact, none of these gentlemen had a right to claim it as his peculiar invention, as the principle was known and recognized long before. I had increased the magnifying powers of telescopes on the same principle several years before any of these gentlemen communicated their views on the subject, although I never formerly constructed a scale of powers. Mr. B. Martin, who died in 1782, proposed, many years before, such a movable interior tube as that alluded to for varying the magnifying power.

In order to give the reader a more specific idea of this contrivance, I shall present him with a figure and description of one of Dr. Kitchener's pancratic eyepieces, copied from one lately in my possession. The following are the exact dimensions of this instrument, with the focal distances, &c., of the glasses, &c., of which it is composed.

| | In. | Tenths. |
|---|---|---|
| Length of the whole eyepiece, consisting of four tubes, when fully drawn out, or the distance from *A* to *B*, fig. 81 . . . . . | 14 | 4 |
| Length of the three tubes on which the scale is engraved, from the commencement of the divisions at *B* to their termination at *C* . | 9 | 15 |
| Each division into tens is equal to 3-10ths of an inch. | | |
| When the three inner tubes are shut up to *C*, the length of the eyepiece is exactly . . . . | 5 | 5 |
| When these tubes are thus shut up, the magnifying power for a 3½ feet achromatic is 100 times, which is the smallest power. When the inner tuue is drawn out one-third of an inch, or to the first division, the power is 110, &c. | | |
| Focal distance of the lens next the object . . . . . . | 1 | 0 |
| Breadth of ditto . . . . | 0 | 65 |
| The plane side of this glass is next the object. | | |
| Focal distance of the second glass from the object . . . . | 1 | 5 |
| This glass is double and equally convex. | | |
| Breadth . . . | 0 | 5 |
| Distance between these two glasses | 1 | 7 |
| Focal distance of the third or field lens, which is plane on the side next the eye . . . . | 1 | 1 |
| Beadth of ditto . . . . . | 0 | 55 |
| Focal distance of the lens next the eye . . . . . . | 0 | 6 |
| Breadth . . . . . . | 0 | 43 |
| This glass is plane on the side next the eye. | | |
| Distance between the third and fourth glasses . . . . | 1 | 1 |

From the figure and description, the reader will be at no loss to perceive how the magnifying power is ascertained by this eyepiece. If the lowest power for a 44 inch telescope be found to be 100 when the three sliding tubes are shut into the larger one, then by drawing out the tube next the eye four divisions, a power of 140 is produced; by drawing out the tube next the eye its whole length, and the second tube to the division marked 220, a power of 220 times is produced; and drawing out all the tubes to their utmost extent, as represented in the figure, a power of 400 is obtained. These powers are by far too high for such a telescope, as the powers between 300 and 400 can seldom or never be used. Were the scale to begin at 50 and terminate at 200, it would be much better adapted to a 3½ feet telescope. Each alteration of the magnifying power requires a new adjustment of the eyepiece for distinct vision. As the magnifying power is increased, the distance between the eyeglass and the object-glass must be diminished. Dr. Kitchener says that "the pancratic eye-tube gives a better defined image of a fixed star, and shows double stars decidedly more distinct and perfectly separated, than any other eyetube, and that such tubes will probably enable us to determine the distances of these objects from each other in a more perfect manner than has been possible heretofore." These tubes are made by Dollond, London, and are sold for two guineas each; but I do not think they excel in distinctness those which are occasionally made by Mr. Tulley and other opticians.

Fig. 81.

## CHAPTER VI.

### *Miscellaneous Remarks in Relation to Telescopes.*

The following remarks, chiefly in regard to the manner of using telescopes, may perhaps be useful to young observers, who are not much accustomed to the mode of managing these instruments.

1. *Adjustments requisite to be attended to in the use of Telescopes.*—When near objects are viewed with a considerable magnifying power, the eyetube requires to be removed further from the object-glass than when very distant objects are contemplated. When the telescope is adjusted for an object 6, 8, or 10 miles distant, a very considerable alteration in the adjustment is requisite in order to see distinctly an object at the distance of two or three hundred yards, especially if the instrument is furnished with a high magnifying power. In this last case, the eyetube requires to be drawn out to a considerable distance beyond the focus for parallel rays. I have found that, in a telescope which magnifies 70 times, when adjusted for an object at the distance of two miles, the adjustment requires to be altered fully one inch in order to perceive distinctly an object at the distance of two or three hundred yards; that is, the tube must be drawn, in this case, an inch further from the object-glass, and pushed in the same extent, when we wish to view an object at the distance of two or three miles. These adjustments are made, in pocket perspectives, by gently sliding the eyetube in or out, by giving it a gentle circular or spiral motion, till the object appear distinct. In using telescopes which are held in the hand, the best plan is to draw all the tubes out to their full length, and then, looking at the object, with the left hand supporting the main tube near the object-glass, and the right supporting the eyetube, gently and gradually push in the eyepiece till distinct vision be obtained. In Gregorian reflecting telescopes this adjustment is made by means of a screw connected with the small speculum; and in large achromatics, by means of a rack and pinion connected with the eyetube. When the magnifying power of a telescope is comparatively small, the eyetube requires to be altered only a very little.

There is another adjustment requisite to be attended to in order to adapt the telescope to the eyes of different persons. Those whose eyes are too convex, or who are short-sighted, require the eyetube to be pushed in, and those whose eyes are somewhat flattened, as old people, require the tube to be drawn out. Indeed, there are scarcely two persons whose eyes do not require different adjustments in a slight degree. In some cases I have found that the difference of adjustment for two individuals, in order to produce distinct vision in each, amounted to nearly half an inch. Hence the difficulty of exhibiting the sun, moon, and planets through telescopes, and even terrestrial objects, to a company of persons who are unacquainted with the mode of using or adjusting such instruments, not one-half of whom generally see the object distinctly; for upon the proper adjustment of a telescope to the eye, the accuracy of vision in all cases depends, and no one except the individual actually looking through the instrument can be certain that it is accurately adjusted to his eye; and even the individual himself, from not being accustomed to the view of certain objects, may be uncertain whether or not the adjustment be correct. I have found by experience that when the magnifying powers are high, as 150 or 200, the difference of adjustment required for different eyes is very slight; but when low powers are used, as 20, 30, or 40, the difference of the requisite adjustments is sometimes very considerable, amounting to a quarter or half an inch.

2. *State of the Atmosphere most proper for observing Terrestrial and Celestial Objects.*—The atmosphere which is thrown around the globe, while it is essentially requisite to the physical constitution of our world, and the comfort of its inhabitants, is found in many instances a serious obstruction to the accurate performance of telescopes. Sometimes it is obscured by mists and exhalations; sometimes it is thrown into violent undulations by the heat of the sun and the process of evaporation; and even, in certain cases, where there appears a pure unclouded azure, there is an agitation among its particles and the substances incorporated with them which prevents the telescope from producing distinct vision either of terrestrial or celestial objects. For viewing distant terrestrial objects, especially with high powers, the best time is early in the morning, a little after sunrise, and from that period till about nine o'clock, A.M. in summer, and in the

evening about two or three hours before sunset. From about ten o'clock. A.M. till four or five in the afternoon, in summer, if the sky be clear and the sun shining, there is generally a considerable undulation in the atmosphere, occasioned by the solar rays and the rapid evaporation, which prevents high powers from being used with distinctness on any telescope, however excellent. The objects at such times, when powers of 50, 70, or 100 are applied, appear to undulate like the waves of the sea, and, notwithstanding every effort to adjust the telescope, they appear confused and indistinct. Even with very moderate magnifying powers this imperfection is perceptible. In such circumstances, I have sometimes used a power of 200 times on distant land objects with good effect a little before sunset, when, in the forenoon of the same day, I could not have applied a power of 50 with any degree of distinctness. On days when the air is clear and the atmosphere covered with clouds, terrestrial objects may be viewed with considerably high powers. When there has been a long continued drought, the atmosphere is then in a very unfit state for enjoying distinct vision with high magnifying powers, on account of the quantity of vapours with which the atmosphere is then surcharged, and the undulations they produce. But, after copious showers of rain, especially if accompanied with high winds, the air is purified, and distant objects appear with greater brilliancy and distinctness than at any other seasons. In using telescopes, the objects at which we look should, if possible, be nearly in a direction opposite to that of the sun. When they are viewed nearly in the direction of the sun, their shadows are turned towards us, and they consequently appear dim and obscure. By not attending to this circumstance, some persons, in trying telescopes, have pronounced a good instrument to be imperfect, which, had it been tried on objects properly illuminated, would have been found to be excellent. In our variable northerly climate the atmosphere is not so clear and serene for telescopic observation as in Italy, the south of France, and in many of the countries which lie within the tropics. The undulations of the air, owing to the causes alluded to above, constitute one of the principal reasons why a telescope magnifying above a hundred times can seldom be used with any good effect in viewing terrestrial objects, though I have sometimes used a power of nearly 200 with considerable distinctness in the stillness of a summer or autumnal evening, when the rays of the declining sun strongly illuminated distant objects.

The atmosphere is likewise frequently a great obstruction to the distinct perception of *celestial* objects. It is scarcely possible for one who has not been accustomed to astronomical observations to form a conception of the very great difference there is in the appearance of some of the heavenly bodies in different states of the atmosphere. There are certain conditions of the atmosphere essentially requisite for making accurate observations with powerful telescopes, and it is but seldom, especially in our climate, that all the favourable circumstances concur. The nights must be very clear and serene—the moon absent—no twilight—no haziness—no violent wind—no sudden change of temperature, as from thaw to frost—and no surcharge of the atmosphere with aqueous vapour. I have frequently found that, on the first and second nights after a thaw, when a strong frost had set in, and when the heavens appeared very brilliant, and the stars vivid and sparkling, the planets, when viewed with high powers, appeared remarkably undefined and indistinct; their margins appeared waving and jagged; and the belts of Jupiter, which at other times were remarkably distinct, were so obscured and ill defined that they could with difficulty be traced. This was probably owing to the quantity of aqueous vapour, and perhaps icy particles, then floating in the air, and to the undulations thereby produced. When a hard frost has continued a considerable time, this impediment to distinct observation is in a great measure removed. But I have never enjoyed more accurate and distinct views of the heavenly bodies than in fresh, serene evenings, when there was no frost and no wind, and only a few fleecy clouds occasionally hovering around. On such evenings, and on such alone, the highest powers may be applied. I have used magnifying powers on such occasions with good effect which could not have been applied, so as to insure distinct vision, more frequently than two or three days in the course of a year.

Sir William Herschel has observed, in reference to this point, "In beautiful nights, when the outside of our telescopes is dropping with moisture, discharged from the atmosphere, there are now and then favourable *hours* in which it is hardly possible to put a limit to the magnifying powers; but such valuable opportunities are extremely scarce, and with large instruments it will always be lost labour to observe at other times. In order, therefore, to calculate how long a time it must take to sweep the heavens, as far as they are within the reach of my forty-feet telescope, charged with a magnifying power of 1000, I I have had recourse to my journals to find how many favourable hours we may annually hope for in this climate; and, under all favourable circumstances, it appears that a year which will afford ninety, or, at most, one hun

dred *hours*, is to be called very productive." "In the equator, with my twenty-feet telescope, I have swept over zones of two degrees with a power of 157, but an allowance of ten minutes in polar distance must be made for lapping the sweeps over one another where they join. As the breadth of the zones may be increased towards the poles, the northern hemisphere may be swept in about 40 zones: to these we must add 19 southern zones; then 59 zones, which, on account of the sweeps lapping over one another about five minutes of time in right ascension, we must reckon of 25 hours each, will give 1475 hours; and allowing 100 hours per year, we find that with the twenty-feet telescope the heavens may be swept in about fourteen years and three quarters. Now the time of sweeping with different magnifying powers will be as the squares of the powers; and putting $p$ and $t$ for the power and time in the twenty-feet telescope, and $P = 1000$ for the power in the forty-feet instrument, we shall have $p^2 : t :: P^2 : \frac{tP^2}{p^2} = 59840$. Then, making the same allowance for 100 hours per year, it appears that it will require not less than 598 years to look with the forty-feet reflector, charged with the above-mentioned power, only one single moment into each point of space; and even then, so much of the southern hemisphere will remain unexplored as will take up 213 years more to examine."*

From the above remarks of so eminent an observer, the reader will perceive how difficult it is to explore the heavens with minuteness and accuracy, and with how many disappointments, arising from the state of the atmosphere, the astronomer must lay his account, when employed in planetary or sidereal investigation. Besides the circumstances now stated, it ought to be noticed that a star or a planet is only in a situation for a high magnifying power about half the time it is above the horizon. The density of the atmosphere, and the quantity of vapours with which it is charged near the horizon, prevent distinct vision of celestial objects with high powers till they have risen to at least 15 or 20 degrees in altitude, and the highest magnifiers can scarcely be applied with good effect unless the object is near the meridian, and at a considerable elevation above the horizon. If the moon be viewed a little after her rising, and afterward when she comes to her highest elevation in autumn, the difference in her appearance and distinctness will be strikingly perceptible. It is impossible to guess whether a night be well adapted for celestial observations till we actually make the experiment, and instruments are frequently condemned, when tried at improper seasons, when the atmosphere only is in fault. A certain observer remarks, "I have never seen the face of Saturn more distinctly than in a night when the air has been so hazy that with my naked eye I could hardly discern a star of less than the third magnitude." The degree of the transparency of the air is likewise varying almost in the course of every minute, so that even in the course of the same half hour planets and stars will appear perfectly defined, and the reverse. The vapours moving and undulating the atmosphere, even when the sky appears clear to the naked eye, will in a few instants destroy the distinctness of vision, and in a few seconds more the object will resume its clear and well-defined aspect."†

3. *On the magnifying Powers requisite for observing the Phenomena of the different Planets, Comets, double Stars, &c.*—There are some objects connected with astronomy which cannot be perceived without having recourse to instruments and to powers of great magnitude; but it is a vulgar error to imagine that very large and very expensive telescopes are absolutely necessary for viewing the greater part of the more interesting scenery of the heavens. Most of the phenomena of the planets, comets, double stars, and other objects, are visible with instruments of moderate dimensions, so that every one who has a relish for celestial investigations may, at a comparatively small expense, procure a telescope for occasional observations which will show the principal objects and phenomena described in books on astronomy. Many persons have been misled by some occasional remarks which Sir W. Herschel made, in reference to certain very high powers which he sometimes put, by way of experiment, on some of his telescopes, as if these were the powers requisite for viewing the objects to which he refers. For example, it is stated that he once put a power of 6450 times on his seven-feet Newtonian telescope of $6\frac{3}{10}$th inches aperture; but this was only for the purpose of an experiment, and could be of no use whatever when applied to the moon, the planets, and most objects in the heavens. Herschel, through the whole course of his writings, mentions his only having used it *twice*, namely, on the stars α Lyræ and γ Leonis, which stars can be seen

* Philosophical Transactions for 1800, vol. xc. p. 89, &c.

† In using telescopes within doors, care should generally be taken that there be no fires in the apartment where they are placed for observation, and that the air within be nearly of the same temperature as the air of the surrounding atmosphere; for if the room be filled with heated air, when the windows are opened there will be a current of cold rushing in, and of heated rushing out which will produce such an undulation and tremulous motion as will prevent any celestial object from being distinctly seen.

more distinctly and sharply defined with a power of 420. To produce a power of 6450 on such a telescope would require a lens of only $\frac{1}{77}$th of an inch in focal distance; and it is questioned by some whether Herschel had lenses of so small a size in his possession, or whether it is possible to form them with accuracy.

*Powers requisite for observing the Phenomena of the Planets.*—The planet *Mercury* requires a considerable magnifying power in order to perceive its phases with distinctness. I have seldom viewed this planet with a less power than 100 and 150, with which powers its half moon, its gibbous, and its crescent phase may be distinctly perceived. With a power of 40, 50, or even 60 times, these phases can with difficulty be seen, especially as it is generally at a low altitude when such observations are made. The phases of *Venus* are much more easily distinguished, especially the *crescent* phase, which is seen to the greatest advantage about a month before and after the inferior conjunction. With a power not exceeding 25 or 30 times, this phase, at such periods, may be easily perceived. It requires, however, much higher powers to perceive distinctly the variations of the gibbous phase; and if this planet be not viewed at a considerably high altitude when in a half-moon or gibbous phase, the obscurity and undulations of the atmosphere near the horizon prevent such phases from being accurately distinguished, even when high powers are applied. Although certain phenomena of the planets may be seen with such low powers as I have now stated, yet in every instance the highest magnifying powers consistent with distinctness should be preferred, as the eye is not then strained, and the object appears with a greater degree of magnitude and splendour. The planet *Mars* requires a considerable degree of magnifying power, even when at its nearest distance from the earth, in order to discern its spots and its gibbous phase. I have never obtained a satisfactory view of the spots which mark the surface, and their relative position, with a less power than 130, 160, or 200 times; and even with such powers, persons not much accustomed to look through telescopes find a difficulty in distinguishing them.

The strongest and most prominent *belts of Jupiter* may be seen with a power of about 45, which power may be put upon a twenty-inch achromatic or a one-foot reflector; but a satisfactory view of all the belts, and the relative positions they occupy, cannot be obtained with much lower powers than 80, 100, or 140. The most common positions of these belts are, one dark and well-defined belt to the south of Jupiter's equator; another of nearly the same description to the north of it, and one about his north and his south polar circles. These polar belts are much more faint and, consequently, not so easily distinguished as the equatorial belts. The *moons* of this planet, in a very clear night, may sometimes be seen with a pocket one-foot achromatic glass, magnifying about 15 or 16 times. Some people have pretended that they could see some of these satellites with their naked eye; but this is very doubtful, and it is probable that such persons mistook certain fixed stars which happened to be near Jupiter for his satellites. But, in order to have a clear and interesting view of these, powers of at least 80 or 100 times should be used. In order to perceive their immersions into the shadow of Jupiter, and the exact moment of their emersions from it, a telescope not less than a 44 inch achromatic, with a power of 150, should be employed. When these satellites are viewed through large telescopes with high magnifying powers, they appear with well-defined disks, like small planets. The planet Jupiter has generally been considered as a good test by which to try telescopes for celestial purposes. When it is near the meridian and at a high altitude, if its general surface, its belts, and its margin appear distinct and well defined, it forms a strong presumptive evidence that the instrument is a good one.

The planet *Saturn* forms one of the most interesting objects for telescopic observation. The *ring* of Saturn may be *seen* with a power of 45; but it can only be contemplated with advantage when powers of 100, 150, and 200 are applied to a three or a five feet achromatic. The *belts of Saturn* are not to be seen distinctly with an achromatic of less than $2\frac{3}{4}$th inches aperture, or a Gregorian reflector of less than four inches aperture, nor with a less magnifying power than 100 times. Sir W. Herschel has drawn this planet with five belts across its disk; but it is seldom that above one or two of them can be seen by moderate-sized telescopes and common observers. The *division* of the double ring, when the planet is in a favourable position for observation, and in a high altitude, may sometimes be perceived with a 44 inch achromatic, with an aperture of $2\frac{3}{4}$th inches, and with powers of 150 or 180; but higher powers and larger instruments are generally requisite to perceive this phenomenon distinctly; and even when a portion of it is seen at the extremities of the *ansæ*, the division cannot, in every case, be traced along the whole of the half-circumference of the ring which is presented to our eye. Mr. Hadley's engraving of Saturn, in the "Philosophical Transactions" for 1723, though taken with a Newtonian reflector with a power of 228, represents the division of the

ring as seen only on the ansæ or extremities of the elliptic figure in which the ring appears. The best period for observing this division is when the ring appears at its utmost width. In this position it was seen in 1840, and it will appear nearly in the same position in 1855. When the ring appears like a very narrow ellipse a short time previous to its disappearance, the division, or dark space between the rings, cannot be seen by ordinary instruments.

Sir W. Herschel very properly observes, "There is not, perhaps, another object in the heavens that presents us with such a variety of extraordinary phenomena as the planet Saturn: a magnificent globe, encompassed by a stupendous double ring; attended by seven satellites; ornamented with equatorial belts; compressed at the poles; turning upon its axis; mutually eclipsing its ring and satellites, and eclipsed by them; the most distant of the rings also turning upon its axis, and the same taking place with the furthest of the satellites; all the parts of the system of Saturn occasionally reflecting light on each other; the rings and moons illuminating the nights of the Saturnian, the globe and satellites enlightening the dark parts of the ring; and the planet and rings throwing back the sun's beams upon the moons, when they are deprived of them at the time of their conjunctions." This illustrious astronomer states that with a new seven feet mirror of extraordinary distinctness he examined this planet, and found that the ring reflects more light than the body, and with a power of 570 the colour of the body becomes yellowish, while that of the ring remains more white. On March 11, 1780, he tried the powers of 222, 332, and 440 successively, and found the light of Saturn less intense than that of the ring; the colour of the body turning, with the high powers, to a kind of yellow white, while that of the ring still remained white.

Most of the *satellites* of Saturn are difficult to be perceived with ordinary telescopes, excepting the fourth, which may be seen with powers of from 60 to 100 times. It was discovered by Huygens in 1655 by means of a common refracting telescope 12 feet long, which might magnify about 70 times. The next in brightness to this is the fifth satellite, which Cassini discovered in 1671 by means of a 17 feet refractor, which might carry a power of above 80 times. The third was discovered by the same astronomer in 1672 by a longer telescope; and the first and second in 1684, by means of two excellent object-glasses of 100 and 136 feet, which might have magnified from 200 to 230 times. They were afterwards seen by two other glasses of 70 and 90 feet, made by Campani, and sent from Rome to the Royal Observatory at Paris by the king's order, after the discovery of the third and fifth satellites. It is asserted, however, that all those five satellites were afterward seen with a telescope of 34 feet, with an aperture of $\frac{3}{10}$th inches, which would magnify about 120 times. These satellites, on the whole, except the fourth and fifth, are not easily detected. Dr. Derham, who frequently viewed Saturn through Huygen's glass of 126 feet focal length, declares, in the preface to his "Astro-Theology," that he could never perceive above three of the satellites. Sir W. Herschel observes, that the visibility of these minute and extremely faint objects depends more on the *penetrating* than upon the *magnifying* power of our telescopes; and that with a ten feet Newtonian, charged with a magnifying power of only 60, he saw all the five old satellites; but the sixth and seventh, which were discovered and were easily seen with his forty feet telescope, and were also visible in his twenty feet instrument, were not discernible in the seven or the ten feet telescopes, though all that *magnifying power* can do may be done as well with the seven feet as with any larger instrument. Speaking of the seventh satellite, he says, "Even in my forty feet reflector it appears no bigger than a very small lucid point. I see it, however, very well in the twenty feet reflector, to which the exquisite figure of the speculum not a little contributes." A late observer asserts that in 1825, with a twelve feet achromatic, of seven inches aperture, made by Tulley, with a power of 150, the seven satellites were easily visible, but not so easily with a power of 200; and that the planet appeared as bright as brilliantly burnished silver, and the division in the ring and a belt were very plainly distinguished with a power of 200.

The planet *Uranus*, being generally invisible to the naked eye, is seldom an object of attention to common observers. A considerable magnifying power is requisite to make it appear in a planetary form with a well defined disk. The best periods for detecting it are when it is near its opposition to the sun, or when it happens to approximate to any of the other planets, or to a well known fixed star. When none of these circumstances occur, its position requires to be pointed out by an equatorial telescope. On the morning of the 25th of January, 1841, this planet happened to be in conjunction with Venus, at which time it was only four minutes north of that planet. Several days before this conjunction I made observations on Uranus. On the evening of the 24th, about eight hours before the conjunction, the two planets appeared in the same field of the telescope, the one exceedingly splendid, and the other more

obscure, but distinct and well defined. Uranus could not be perceived either with the naked eye or with an opera-glass, but could be distinguished as a very small star by means of a pocket achromatic telescope magnifying about 14 times. It is questionable whether, under the most favourable circumstances, this planet can ever be distinguished by the naked eye. With magnifying powers of 30 and 70, it appeared as a moderately large star with a steady light, but without any sensible disk. With powers of 120, 180, and 250, it presented a round and pretty well defined disk, but not so luminous and distinct as it would have done in a higher altitude.

The *Double Stars* require a great *variety* of powers in order to distinguish the small stars that accompany the larger. Some of them are distinguished with moderate powers, while others require pretty large instruments, furnished with high magnifying eyepieces. I shall therefore select only a few as a specimen. The star *Castor*, or α Geminorum, may be easily seen to be double with powers of from 70 to 100. I have sometimes seen these stars, which are nearly equal in size and colour, with a terrestrial power of 44 on a 44 inch achromatic. The appearance of this star with such powers is somewhat similar to that of η Coronæ in a seven feet achromatic of five inches aperture, with a power of 500. γ Andromedæ may be seen with a moderate power. In a thirty inch achromatic of two inches aperture and a power of 80, it appears like ε Bootis when seen in a five feet achromatic with a power of 460. This star is said to be visible even in a one foot achromatic with a power of 35. ε *Lyræ*, which is a quintuple star, but appears to the naked eye as a single star, may be seen to be double with a power of from six to twelve times. γ *Leonis* is visible in a 44 inch achromatic with a power of 180 or 200. *Rigel* in a 3½ feet achromatic, may be seen with powers varying from 130 to 200. The small star, however, which accompanies Rigel, is sometimes difficult to be perceived, even with such powers. ε *Bootis* is seldom distinctly defined with an achromatic of less aperture than 3¼th inches, or a reflector of less than five inches, with a power of at least 250.

These and similar stars are not to be expected to be seen equally well at all times, even when the magnifying and illuminating powers are properly proportioned, as much depends upon the state of the weather, and the pureness of the atmosphere. In order to perceive the closest of the double stars, Sir W. Herschel recommends that the power of the telescope should be adjusted upon a star known to be single, of nearly the same altitude, magnitude, and colour with the double star which is to be observed, or upon one star above and another below it. Thus the late Mr. Albert, the astronomer, could not see the two stars of γ Leonis when the focus was adjusted upon that star itself, but he soon observed the small star after he had adjusted the focus upon Regulus. An exact adjustment of the focus of the instrument is indispensably requisite in order to perceive such minute objects.

In viewing the *Nebulæ*, and the very small and immensely distant fixed stars, which require much light to render them visible, a large aperture of the object-glass or speculum, which admits of a great quantity of light, is of more importance than high magnifying powers. It is light chiefly, accompanied with a moderate magnifying power, that enables us to *penetrate* into the distant regions of space. Sir W. Herschel, when sweeping the profundities of the Milky Way, and the Hand and Club of Orion, used a telescope of the Newtonian form, twenty feet focal length and $18\frac{7}{10}$th inches in diameter, with a power of only 157. On applying this telescope and power to a part of the *Via Lactea*, he found that it completely resolved the whole whitish appearance into stars, which his former telescopes had not light enough to effect, and which smaller instruments with much higher magnifying powers would not have effected. He tells us that, with this power, "the glorious multitude of stars," in the vicinity of Orion, "of all possible sizes, that presented themselves to view, was truly astonishing, and that he had fields which contained 70, 90, and 110 stars, so that a belt of fifteen degrees long and two degrees broad, which passed through the field of the telescope in an hour, could not contain less than fifty thousand stars that were large enough to be distinctly numbered." In viewing the Milky Way, the Nebulæ, and small cluster of stars, such as *Præcepe* in Cancer, I generally use a power of 55 times on an achromatic telescope six feet six inches in focal length and four inches in diameter. The eyepiece which produces this power—which I formed for the purpose—consists of two convex lenses, the one next the eye three inches focal length and $1\frac{3}{10}$ths of an inch diameter, and that next the object 3½ inches focus and $1\frac{4}{10}$ths of an inch diameter, the deepest convex surfaces being next each other, and their distance a quarter of an inch. With this eyepiece a very large and brilliant field of view is obtained; and I find it preferable to any higher powers in viewing the nebulosities and clusters of stars. In certain spaces of the heavens it sometimes presents in one field nearly a hundred stars. It likewise serves to exhibit a very clear and interesting view of the full moon.

In observing *Comets*, a very small power should generally be used, even on large instruments. These bodies possess so small a quantity of light, and they are so frequently enveloped in a veil of dense atmosphere, that *magnifying* power sometimes renders them more obscure, and therefore the *illuminating* power of a large telescope with a small power is in all cases to be preferred. A comet eyepiece should be constructed with a very large and uniformly distinct field, and should magnify only from 15 to 30 or 40 times, and the lenses of such an eyetube should be nearly two inches in diameter. The late Rev. F. Wollaston recommended for observing comets "a telescope with an achromatic object-glass of 16 inches focal length and two inches aperture, with a Ramsden's eyeglass magnifying about 25 times, mounted on a very firm equatorial stand, the field of view taking in two degrees of a great circle."

In viewing the *moon*, various powers may be applied, according to circumstances. The best periods of the moon for inspecting the inequalities on its surface are either when it assumes a crescent or a half-moon phase, or two or three days after the period of half-moon. Several days after full moon, and particularly about the third quarter, when the orb is waning, and when the shadows of its mountains and vales are thrown in a different direction from what they are when on the increase, the most prominent and interesting views may be obtained. The most convenient season for obtaining such views is during the autumnal months, when the moon, about the third quarter, sometimes rises as early as eight o'clock P.M., and may be viewed at a considerably high altitude by ten or eleven. When in the positions now alluded to, and at a high altitude, very high magnifying powers may sometimes be applied with good effect, especially if the atmosphere be clear and serene. I have sometimes applied a power, in such cases, of 350 times on a 46 inch achromatic with considerable distinctness; but it is only two or three times in a year, and when the atmosphere is remarkably favourable, that such a power can be used. The autumnal evenings are generally best fitted for such observations. The *full moon* is an object which is never seen to advantage with high powers, as no shadows or inequalities on its surface can then be perceived. It forms, however, a very beautiful object when magnifying powers not higher than 40, 50, or 60 times are used. A power of 45 times, if properly constructed, will show the *whole of the moon* with a margin around it, when the darker and brighter parts of its surface will present a variegated aspect, and appear somewhat like a map to the eye of the observer.

4. *Mode of exhibiting the Solar Spots.*—The solar spots may be contemplated with advantage by magnifying powers varying from 60 to 180 times; about 90 times is a good medium power, though they may sometimes be distinguished with very low powers, such as those usually adapted to a one-foot telescope, or even by means of a common opera-glass. The common astronomical eyepieces given along with achromatic telescopes, and the sunglasses connected with them, are generally ill adapted for taking a pleasant and comprehensive view of the solar spots. In the higher magnifying powers, the first eyeglass is generally at too great a distance from the eye, and the sunglass which is screwed over it removes it to a still greater distance from the point to which the eye is applied, so that not above one-third of the field of view can be taken in. The circumstance renders it difficult to point the instrument to any particular small spot on the solar disk which we wish minutely to inspect; and besides, it prevents us from taking a comprehensive view of the *relative positions* of all the spots that may at any time be traversing the disk. To obviate this inconvenience, the sunglass would require to be placed so near to the glass next the eye as almost to touch it. But this is sometimes difficult to be attained, and, in high powers, even the thickness of the sunglass itself is sufficient to prevent the eye from taking in the whole field of view. For preventing the inconveniences to which I now allude, I generally make use of a *terrestrial* eyepiece of a considerable power, with a large field; the sunglass is fixed at the end of a short tube, which slides on the eyepiece, and permits the coloured glass to approach within a line or two of the lens next the eye, so that the whole field of the telescope is completely secured. The eyepiece alluded to carries a magnifying power of 95 times for a 46 inch telescope, and takes in about three-fourths of the surface of the sun, so that the relative positions of all the spots may generally be perceived at one view. Such a power is, in most cases, quite sufficient for ordinary observations, and I have seldom found any good effect to arise from attempting very high powers when minutely examining the solar spots.

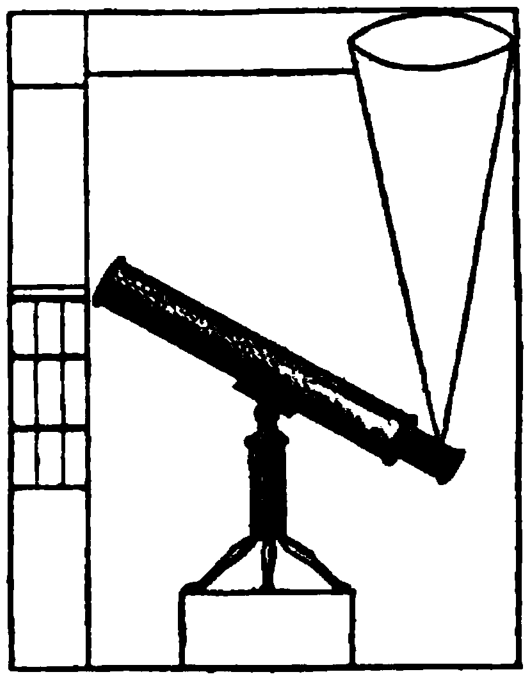
But the most pleasant mode of viewing the solar spots, especially when we wish to exhibit them to others, is to throw the image of the sun upon a white screen, placed in a room which is considerably darkened. It is difficult, however, when the sun is at a high altitude, to put this method into practice, on account of the great obliquity with which his rays then fall, which prevents a screen from being placed at any considerable distance from

the eye-end of the telescope. The following plan, therefore, is that which I uniformly adopt, as being both the easiest and the most satisfactory. A telescope is placed in a convenient position, so as to be directed to the sun. This telescope is furnished with a *diagonal eyepiece*, such as that represented in fig. 77 (p. 123.) The window-shutters of the apartment are all closed excepting a space sufficient to admit the solar rays; and when the telescope is properly adjusted, a beautiful image of the sun, with all the spots which then happen to diversify his surface, is thrown upon the *ceiling* of the room. This image may be from 12 to 20, or 30 inches or more in diameter, according to the distance of the ceiling from the diagonal eyepiece. The greater this distance is, the larger the image. If the sun is at a very high altitude, the image will be elliptical; if he be at no great distance from the horizon, the image will appear circular, or nearly so; but in either case the spots will be distinctly depicted, provided the focus of the telescope be accurately adjusted. In this exhibition, the apparent motion of the sun produced by the rotation of the earth, and the passage of thin fleeces of clouds across the solar disk, exhibit a very pleasing appearance.

By this mode of viewing the solar spots we may easily ascertain their diameter and magnitude, at least to a near approximation. We have only to take a scale of inches, and measure the diameter of any well-defined and remarkable spot, and then the diameter of the solar image; and, comparing the one with the other, we can ascertain the number of miles, either lineal or square, comprehended in the dimensions of the spot. For example, suppose a spot to measure half an inch in diameter, and the whole image of the sun 25 inches, the proportion between the diameter of the spot and that of the sun will be as 1 to 50; in other words, the *one-fiftieth* part of the sun's diameter. Now this diameter being 880,000 miles, this number, divided by 50, produces a quotient of 17,600=the number of miles which its diameter measures. Such a spot will therefore contain an area of 243,-285,504, or more than two hundred and forty-three millions of square miles, which is 46 millions of miles more than the whole superficies of the terraqueous globe. Again, suppose the diameter of a spot measures $\frac{3}{10}$ths of an inch, and the solar image 23 inches, the proportion of the diameter of the spot to that of the sun is as 3 to 230=the number of tenths in 23 inches. The number of miles in the spot's diameter will therefore be found by the following proportion: 230 : 880,000 : : 3 : 11,478; that is, the diameter of such a spot measures eleven thousand four hundred and seventy-eight miles. Spots of such sizes are not unfrequently seen to transit the solar disk.

By this mode of viewing the image of the sun, his spots may be exhibited to twenty or thirty individuals at once without the least straining or injury to the eyes; and as no separate screen is requisite, and as the ceilings of rooms are generally white, the experiment may be performed in half a minute without any previous preparation except screwing on and adjusting the eyepiece. The manner of exhibiting the solar spots in this way is represented in fig. 82.

Fig. 82.



5. *On the Space-penetrating Power of Telescopes.*—The power of telescopes to penetrate into the profundity of space is the result of the quantity of light they collect and send to the eye in a state fit for vision. This property of telescopes is sometimes designated by the expression *Illuminating Power.*

Sir W. Herschel appears to have been the first who made a distinction between the *magnifying* power and the *space-penetrating* power of a telescope; and there are many examples which prove that such a distinction ought to be made, especially in the case of large instruments. For example, the small star, or speck of light, which accompanies the pole star, may be seen through a telescope of large aperture with a smaller magnifying power than with a telescope of a small aperture furnished with a much higher power. If the magnifying power is sufficient to show the small star completely separated from the rays which surround the large one, this is sufficient in one point of view; but, in order that this effect may be produced, so as to render the small star perfectly distinguishable, a certain quantity of light must be admitted into the pupil of the eye, which quantity depends upon the area of the object-glass or speculum of the instrument, or, in other words, on the illuminating power. If we compare a tele-

scope of 2¾th inches aperture with one of five inches aperture, when the magnifying power of each does not exceed 50 times for terrestrial objects, the effect of illuminating power is not so evident; but if we use a power of 100 for day objects, and 180 for the heavenly bodies, the effects of illuminating power is so clearly perceptible, that objects not only appear brighter and more clearly visible in the larger telescope, but with the same magnifying power they also *appear* larger, particularly when the satellites of Jupiter and small stars are the objects we are viewing.

Sir W. Herschel remarks, that "objects are viewed in their greatest perfection when, in penetrating space, the magnifying power is so low as only to be sufficient to show the object well, and when, in magnifying objects, by way of examining them minutely, the space-penetrating power is no higher than what will suffice for the purpose; for in the use of either power, the injudicious overcharge of the other will prove hurtful to vision." When illuminating power is in too high a degree, the eye is offended by the extreme brightness of the object; when it is in too low a degree, the eye is distressed by its endeavours to see what is beyond its reach; and therefore it is desirable, when we wish to give the eye all the assistance possible, to have the illuminating and the magnifying powers in due proportion. What this proportion is, depends, in a certain degree, upon the brightness of the object. In proportion to its brightness or luminosity, the magnifying power may, to a certain extent, be increased. Sir W. Herschel remarks, in reference to $\alpha$ Lyræ, "This star, I surmise, has light enough to bear being magnified at least a hundred thousand times, with no more than six inches of aperture." However beautifully perfect any telescopes may appear, and however sharp their *defining* power, their performance is limited by their illuminating powers, which are as the squares of the diameters of the apertures of the respective instruments. Thus a telescope whose object-glass is four inches diameter will have four times the quantity of light, or illuminating power, possessed by a telescope whose aperture is only two inches, or in the proportion of 16 to 4; the square of 4 being 16, and the square of 2 being 4.

The nature of the *space-penetrating power* to which we are adverting, and the distinction between it and magnifying power, may be illustrated from a few examples taken from Sir W. Herschel's observations.

The first observation which I shall notice refers to the *nebula* between $\eta$ and $\zeta$ Ophiuchi, discovered by Messier in 1764. The observation was made with a ten-feet reflector, having a magnifying power of 250, and a space-penetrating power of 28.67. His note is dated May 3, 1783. "I see several stars in it, and make no doubt a higher power and more light will resolve it all into stars. This seems to me a good nebula for the purpose of establishing the connexion between nebulæ and clusters of stars in general." "June 18, 1784. The same nebula viewed with a Newtonian twenty-feet reflector; penetrating power 61, and a magnifying power of 157; a very large and a very bright cluster of excessively compressed stars. The stars are but just visible, and are of unequal magnitudes. The large stars are red; the cluster is a miniature of that near Flamstead's forty-second Comæ Berenices. Right ascension, $17^h$ $6^m$ $32^s$ Polar distance, 108° 18″." In this case, a penetrating power of about 28, with a magnifying power of 250, barely showed a few stars; while in the second instrument the illuminating power of 60, with the magnifying power of only 157, showed them completely.

Subsequently to the date of the latter observation, the twenty-feet Newtonian telescope was converted into an Herschelian instrument by taking away the small speculum, and giving the large one the proper inclination for obtaining the front view; by which alteration the illuminating power was increased from 61 to 75, and the advantage derived from the alteration was evident in the discovery of the satellites of Uranus by the altered telescope, which before was incompetent in the point of penetration, or illuminating power. "March 14, 1798, I viewed the Georgian planet (or Uranus) with a new twenty-five-feet reflector. Its penetrating power is 95,85, and having just before also viewed it with my twenty-feet instrument, I found that with an equal magnifying power of 300, the twenty-five-feet telescope had considerably the advantage of the former." The aperture of the twenty-feet instrument was 18.8 inches, and that of the twenty-five-feet telescope 24 inches, so that the superior effect of the latter instrument must have been owing to its greater illuminating power. The following observations show the superior power of the forty-feet telescope, as compared with the twenty-feet. "Feb. 24, 1786, I viewed the nebula near Flamstead's fifth Serpentis with my twenty-feet reflector, magnifying power 157. The most beautiful, extremely compressed cluster of small stars, the greatest part of them gathered together into one brilliant nucleus, evidently consisting of stars, surrounded with many detached gathering stars of the same size and colour. R. A., $15^h$ $7^m$ $12^s$. P. D., 87° 8″." "May 27, 1791, I viewed the same object with my forty-feet telescope, penetrat-

ing power 191.69, magnifying power 370. A beautiful cluster of stars. I counted about 200 of them. The middle of it is so compressed that it is impossible to distinguish the stars." "Nov. 5, 1791, I viewed Saturn with the twenty and forty feet telescopes: *Twenty feet.*—The fifth satellite of Saturn is very small. The first, second, third, fourth, and fifth, and the new sixth satellites, are in their calculated places. *Forty feet.*—I see the new sixth satellite much better with this instrument than with the twenty-feet. The fifth is also much larger here than in the twenty-feet, in which it was nearly the same size as a small fixed star, but here it is considerably larger than that star."

These examples, and many others of a similar kind, explain sufficiently the nature and extent of that species of power that one telescope possesses over another, in consequence of its enlarged aperture; but the exact quantity of this power is in some degree uncertain. To ascertain practically the illuminating power of telescopes, we must try them with equal powers on such objects as the following: the small stars near the pole star, and near Rigel and ε Bootis; the division in the ring of Saturn; and distant objects in the twilight or towards the evening. These objects are distinctly seen with a five-feet achromatic of $3\frac{8}{10}$th inches aperture, and an illuminating power of 144, while they are scarcely visible in a 3½ feet with an aperture of 2¾th inches, and an illuminating power of 72, supposing the same magnifying power to be applied. The illuminating power of a telescope is best estimated, in regard to land objects, when it is tried on minute objects, and such as are badly lighted up; and the advantage of a telescope with a large aperture will be most obvious when it is compared with another of inferior size in the close of the evening, when looking at a printed bill composed of letters of various sizes. As darkness comes on, the use of illuminating power becomes more evident. In a five-feet telescope some small letters will be legible which are hardly discernible in the 3½ feet, and in the 2½ feet are quite undefinable, though the magnifying powers be equal. Sir W. Herschel informs us that, in the year 1776, when he had erected a telescope of twenty feet focal length of the Newtonian construction, one of its effects by trial was, that when, towards evening, on account of darkness, the natural eye could not penetrate far into space, the telescope possessed that power sufficiently to show, by the dial of a distant church steeple, what o'clock it was, notwithstanding the naked eye could no longer see the steeple itself.

In order to convey an idea of the *numbers* by which the degree of space-penetrating power is expressed, and the general grounds on which they rest, the following statements may be made. The depth to which the naked eye can penetrate into the spaces of the heavens is considered as extending to the twelfth order of distances; in other words, it can perceive a star at a distance twelve times further than those luminaries, such as Sirius, Arcturus, or Capella, which, from their vivid light, we presume to be nearest to us. It has been stated above that Herschel calculated his ten-feet telescope to have a space-penetrating power of 28.67, that is, it could enable us to descry a star 28 times further distant than the naked eye can reach. His twenty-feet Newtonian was considered as having a similar power of 61; his 25 feet, nearly 96; and his forty-feet instrument, a power of 191.69. If each of these numbers be multiplied by 12, the product will indicate how much further these telescopes will penetrate into space than the nearest range of the fixed stars, such as those of the first magnitude. For instance, the penetrating power of the forty-feet reflector being 191.69, this number, multiplied by 12, gives a product of 2300, which shows that, were there a series of two thousand three hundred stars extended in a line beyond Sirius, Capella, and similar stars, each star separated from the one beyond it by a space equal to the distance of Sirius from the earth, they might be all seen through the forty-feet telescope. In short, the penetrating power of telescopes is a circumstance which requires to be particularly attended to in our observations of celestial phenomena, and in many cases is of more importance than *magnifying* power. It is the effect produced by illuminating power that renders telescopes, furnished with comparatively small magnifying powers, much more efficient in observing comets, and certain nebulæ and clusters of stars, than when high powers are attempted. Every telescope may be so adjusted as to produce different space-penetrating powers. If we wish to diminish such a power, we have only to contract the object-glass or speculum by placing circular rims, or apertures of different degrees of breadth, across the mouth of the great tube of the instrument. But we cannot increase this illuminating power beyond a certain extent, which is limited by the diameter of the object-glass. When we wish illuminating power beyond this limit, we must be furnished with an object-glass or speculum of a larger size; and hence the rapid advance in price of instruments which have large apertures, and consequently high illuminating powers. Mr. Tulley's 3½ feet achromatics of 2¾th inches aperture sell at £26 5s.; when the aperture is 3¼th inches, the price is £42; when 3¾th inches, £68 5s. The following table con-

tains a statement of the "comparative lengths, apertures, illuminating powers, and prices of achromatic refractors and Gregorian reflectors," according to Dr. Kitchener:

| ACHROMATIC REFRACTORS. | | | |
|---|---|---|---|
| Length and name they are known by. | Diameter of aperture. | Illuminating power. | Price. |
| Feet. | In. Th. | | L. s. |
| 2 | 1. 6 | 25 | 4 4 |
| 2½ | 2 | 40 | 12 12 |
| 3½ | 2. 7 | 72 | 21 to 42 |
| 5 | 3. 8 | 144 | 105 to 150 |
| 7 | 5 | 250 | 250 |
| 7 | 6 | 360 | 360 |

| GREGORIAN, ETC., REFLECTORS. | | | |
|---|---|---|---|
| Length and name they are known by | Diameter of aperture. | Illuminating power. | Price. |
| Feet. | In. Th. | | L. s. |
| 1 | 2. 5 | 62 | 7 7 |
| 1½ | 3 | 90 | 12 12 |
| 2 | 4. 5 | 202 | 20 |
| 3 | 5. 5 | 302 | 50 |
| 4 | 7 | 490 | 105 |
| 7 Newtonian | 7 | 490 | 126 |
| 5 Gregorian | 9 | 810 | 200 |
| 10 Newtonian | 10 | 1000 | 315 |

The illuminating powers stated in the above table are only comparative. Fixing on the number 25 as the illuminating power of a two-feet telescope, $1\frac{6}{10}$ths of an inch aperture, that of a 2½ feet, two inches aperture, will be 40; of a five-feet, $3\frac{8}{10}$th inches aperture, 144, &c. If the illuminating power of a Gregorian 1½ foot, and three inches aperture, be 90, a five-feet, with nine inches aperture, will be 810, &c.

6. *On choosing Telescopes, and ascertaining their Properties.*—It is an object of considerable importance to every astronomical observer that he should be enabled to form a judgment of the qualities of his telescope, and of any instruments of this description which he may intend to purchase. The following directions may perhaps be useful to the reader in directing him in the choice of an achromatic refracting telescope:

Supposing that an achromatic telescope of 3½ feet focal length and 3¼th inches aperture were offered for sale, and that it were required to ascertain whether the object-glass, on which its excellence chiefly depends, is a good one, and duly adjusted, some opinion may be formed by laying the tube of the telescope in a horizontal position, on a firm support, about the height of the eye, and by placing a printed card or a watch-glass vertically, but in an inverted position, against some wall or pillar at 40 or 50 yards distant, so as to be exposed to a clear sky. When the telescope is directed to this object, and accurately adjusted to the eye, should the letters on the card, or the strokes and dots on the watch-glass, appear clearly and sharply defined, without any mistiness or coloration, and if very small spots appear well defined, great hopes may be entertained that the glass will turn out a good one. But a telescope may appear a good one, when viewing common terrestrial objects, to eyes unaccustomed to discriminate deviations from perfect vision, while it may turn out to be an indifferent one when directed to certain celestial objects. Instead, therefore, of a printed card, fix a black board, or one half of a sheet of black paper, in a vertical position at the same distance, and a circular disk of white writing paper, about one-fourth of an inch in diameter, on the centre of the black ground; then, having directed the telescope to this object, and adjusted for the place of distinct vision, mark with a black-lead pencil the sliding eyetube at the end of the main tube, so that this position can always be known; and if this sliding tube be gradually drawn out or pushed in while the eye beholds the disk, it will gradually enlarge and lose its colour till its edges cease to be well defined. Now if the enlarged misty circle is observed to be concentric with the disk itself, the object-glass is properly centred, as it has reference to the tube; but if the misty circle goes to one side of the disk, the cell of the object-glass is not at right angles to the tube, and must have its screws removed and its holes elongated by a rat-tailed file small enough to enter the holes. When this has been done, the cell may be replaced, and the disk examined a second time, and a slight stroke on one edge of the cell by a wooden mallet will show by the alteration made in the position of the misty portion of the disk how the adjustment is to be effected, which is known to be right when a motion in the sliding tube will make the diluted disk enlarge in a circle concentric with the disk itself. When the disk will enlarge so as to make a ring of diluted white light round its circumference as the sliding tube holding the eyepiece is pushed in or drawn out, the cell may be finally fixed by the screws passing through its elongated holes.

When the object-glass is thus adjusted, it may then be ascertained whether the curves of the respective lenses composing the object-glass are well formed, and suitable for each other. If a small motion of the sliding tube of about $\frac{1}{10}$th of an inch in a 3½ feet telescope from the point of distinct vision will dilute the light of the disk and render the appearance confused, the figure of the object-glass is good, particularly if the same effect will take place at equal distances from the point of distinct

vision when the tube is alternately drawn out and pushed in. A telescope that will admit of much motion in the sliding tube without sensibly affecting the distinctness of vision will not define an object well at any point of adjustment, and must be considered as having an imperfect object-glass, inasmuch as the spherical aberration of the transmitted rays is not duly corrected. The due adjustment of the convex lens or lenses to the cancave one will be judged of by the absence of coloration round the enlarged disk, and is a property distinct from the spherical aberration; the achromatism depending on the relative focal distances of the convex and concave lenses is regulated by the relative dispersive powers of the pieces of glass made use of, but the distinctness of vision depends on a good figure of the computed curves that limit the focal distances. When an object-glass is free from imperfection in both these respects, it may be called a good glass for terrestrial purposes.

It still, however, remains to be determined how far such an object-glass may be good for viewing a star or a planet, and can only be known by actual observations on the heavenly bodies. When a good telescope is directed to the moon or to Jupiter, the achromatism may be judged of by alternately pushing in and drawing out the eyepiece from the place of distinct vision. In the former case, a ring of purple will be formed round the edge; and in the latter, a ring of light green, which is the central colour of the prismatic spectrum; for these appearances show that the extreme colours, red and violet, are corrected. Again, if one part of a lens employed have a different refractive power from another part of it, that is, if the flint-glass particularly is not homogeneous, a star of the first and even of the second magnitude will point out the natural defect by the exhibition of an irradiation, or what is called *a wing*, at one side, which no perfection of figure or of adjustment will banish, and the greater the aperture, the more liable is the evil to happen: hence caps with different apertures are usually supplied with large telescopes, that the extreme parts of the glass may be cut off in observations requiring a round and well-defined image of the body observed.

Another method of determining the figure and quality of an object-glass is by first covering its centre by a circular piece of paper, as much as one half of its diameter, and adjusting it for distinct vision of a given object, such as the disk above mentioned, when the central rays are intercepted, and then trying if the focal length remains unaltered when the paper is taken away and an aperture of the same size applied, so that the extreme rays may in their turn be cut off. If the vision remains equally distinct in both cases, without any new adjustment for focal distance, the figure is good, and the spherical aberration cured, and it may be seen by viewing a star of the first magnitude successively in both cases, whether the irradiation is produced more by the extreme or by the central parts of the glass; or, in case the one half be faulty and the other good, a semicircular aperture, by being turned gradually round in trial, will detect what semicircle contains the defective portion of the glass; and if such portion should be covered, the only inconvenience that would ensue would be the loss of so much light as is thus excluded. When an object-glass produces radiations in a large star, it is unfit for the nicer observations of astronomy, such as viewing double stars of the first class. The smaller a large star appears in any telescope, the better is the figure of the object-glass; but if the image of the star be free from wings, the size of its disk is not an objection in practical observations.*

Some opticians are in the habit of inserting a diaphragm into the body of the large tube, to cut off the extreme rays coming from the object-glass when the figure is not good, instead of lessening the aperture by a cap. When this is the case, a deficiency of light will be the consequence beyond what the apparent aperture warrants. It is therefore proper to examine that the diaphragm be not placed too near the object-glass, so as to intercept any of the useful rays. Sometimes a portion of the object-glass is cut off by the stop in the eyetube. To ascertain this, adjust the telescope to distinct vision, then take out the eyeglasses, and put your finger on some other object on the edge of the outside of the object-glass, and look down the tube; if you can see the top of your finger, or any object in its place, just peeping over the edge of the object-glass, no part is cut off. I once had a 3½ feet telescope whose object-glass measured three inches in diameter, which was neither so bright, nor did it perform in other respects nearly so well as another of the same length whose object-glass was only 2¾th inches in diameter; but I found that a diaphragm was placed about a foot within the end of the large tube, which reduced the aperture of the object-glass to less than 2½ inches, and when it was removed the telescope was less distinct than before. The powers given along with this instrument were much lower than usual, none of them exceeding 100 times. This is a trick not uncommon with some opticians.

Dr. Pearson mentions that an old Dollond's telescope of 63 inches focal length and 3¾th

* The above directions and remarks are abridged with some alterations from Dr. Pearson's "Introduction to Practical Astronomy," vol. ii.

inches aperture, supposed to be an excellent one, was brought to Mr. Tulley when he was present, and the result of the examination was that its achromatism was not perfect. The imperfection was thus determined by experiment. A small glass globe was placed at forty yards' distance from the object-end of the telescope when the sun was shining, and the speck of light seen reflected from this globe formed a good substitute for a large star, as an object to be viewed. When the focal length of the object-glass was adjusted to this luminous object, no judgment could be formed of its prismatic aberrations till the eyepiece had been pushed in beyond the place of correct vision; but when the telescope was shortened a little, the luminous disk occasioned by such shortening was strongly tinged with *red* rays at its circumference. On the contrary, when the eyepiece was drawn out so as to lengthen the telescope too much, the disk thus produced was tinged with a small circle of *red* at its *centre*, thereby denoting that the convex lens had too short a focal length; and Mr. Tulley observed, that if one or both of the curves of the convex lens were flattened till the total focal length should be about four inches increased, it would render the telescope quite achromatic, provided in doing this the aberration should not be increased.

The following general remarks may be added: 1. To make any thing like an accurate comparison of telescopes, they must be tried not only at the same place, but as nearly as possible at the same time, and, if the instruments are of the same length and construction, if possible, with the same eyepiece. 2. A difference of eight or ten times in the magnifying power will sometimes, on certain objects, give quite a different character to a telescope. It has been found by various experiments that object-glasses of two or three inches longer focus will produce different vision with the same eyepiece. 3. Care must be taken to ascertain that the eyeglasses are perfectly clean and free from defects. The defects of glass are either from veins, specks, scratches, colour, or an incorrect figure. To discover veins in an eye or an object-glass, place a candle at the distance of four or five yards; then look through the glass, and move it from your eye till it appear full of light; you will then see every vein, or other imperfection in it, which may distort the objects and render vision imperfect. Specks or scratches, especially in object-glasses, are not so injurious as veins, for they do not distort the object, but only intercept a portion of the light. 4. We cannot judge accurately of the excellence of any telescope by observing objects with which we are not familiarly acquainted. Opticians generally try an instrument at their own marks, such as the dial-plate of a watch, a finely-engraved card, a weathercock, or the moon and the planet Jupiter, when near the meridian. Of several telescopes of the same length, aperture, and magnifying power, that one is generally considered the best with which we can read a given print at the greatest distance, especially if the print consists of *figures*, such as a table of logarithms, where the eye is not apt to be deceived by the imagination in *guessing* at the sense of a passage when two or three words are distinguished.

There is a circumstance which I have frequently noticed in reference to achromatic telescopes, particularly those of a small size, and which I have never seen noticed by any optical writer. It is this: if the telescope, when we are viewing objects, be gradually turned round its axis, there is a certain position in which the objects will appear distinct and accurately defined; and if it be turned round exactly a semicircle from this point, the same degree of distinctness is perceived, but in all other positions there is an evident want of clearness and defining power. This I find to be the case in more than ten one-foot and two-feet telescopes now in my possession, and therefore I have put marks upon the object-end of each of them to indicate the positions in which they should be used for distinct observation. This is a circumstance which requires, in many cases, to be attended to in the choice and the use of telescopical instruments, and in fixing and adjusting them on their pedestals. In some telescopes this defect is very striking, but it is in some measure perceptible in the great majority of instruments which I have had occasion to inspect. Even in large and expensive achromatic telescopes this defect is sometimes observable. I have an achromatic whose object glass is $4\frac{1}{10}$th inches diameter, which was much improved in its defining power by being unscrewed from its original position, or turned round its axis about one-eighth part of its circumference. This defect is best detected by looking at a large printed bill, or a signpost at a distance, when on turning round the telescope or object-glass, the letters will appear much better defined in one position than in another. The position in which the object appears least distinct is when the upper part of the telescope is a quadrant of a circle different from the two positions above stated, or at an equal distance from each of them.

7. *On the mode of determining the magnifying Power of Telescopes.*—In regard to refracting telescopes, we have already shown that, when a single eyeglass is used, the magnifying power may be found by dividing the

focal distance of the object-glass by that of the eyeglass; but when a Huygenian eyepiece, or a four-glass terrestrial eyepiece, such as is now common in achromatic telescopes, is used, the magnifying power cannot be ascertained in this manner; and in some of the delicate observations of practical astronomy, it is of the utmost importance to know the exact magnifying power of the instrument with which the observations are made, particularly when micrometrical measurements are employed to obtain the desired results. The following is a general method of finding the magnifying powers of telescopes when the instrument called a *dynameter* is not employed, and it answers for refracting and reflecting telescopes of every description.

Having put up a small circle of paper an inch or two in diameter at the distance of about 100 yards, draw upon a card two black parallel lines, whose distance from each other is equal to the diameter of the paper circle; then view through the telescope the paper circle with one eye, and the parallel lines with the other, and let the parallel lines be moved nearer to or further from the eye, till they seem exactly to cover the small circle viewed through the telescope; the quotient obtained by dividing the distance of the paper circle by the distance of the parallel lines from the eye will be the magnifying power of the telescope. It requires a little practice before this experiment can be performed with accuracy. The one eye must be accustomed to look at an object near at hand, while the other is looking at a more distant object through the telescope. Both eyes must be open at the same time, and the image of the object seen through the telescope must be brought into apparent contact with the real object near at hand. But a little practice will soon enable any observer to perform the experiment with ease and correctness, if the telescope be mounted on a firm stand, and its elevation or depression produced by rack-work.

The following is another method, founded on the same principle: Measure the space occupied by a number of the courses, or rows of bricks in a modern building, which upon an average, is found to have eight courses in two feet, so that each course or row is three inches. Then cut a piece of paper three inches in height, and of the length of a brick, which is about nine inches, so that it may represent a brick, and fixing the paper against the brick wall, place the telescope to be examined at the distance of about 80 or 100 yards from it. Now, looking through the telescope at the paper with one eye, and at the same time, with the other eye, looking past the telescope, observe what extent of wall the magnified image of the paper appears to cover; then count the courses of bricks in that extent and it will give the magnifying power of the telescope. It is to be observed, however, that the magnifying power determined in this way will be a fraction greater than for very distant objects, as the focal distance of the telescope is necessarily lengthened in order to obtain distinct vision of near objects.

In comparing the magnifying powers of two telescopes, or of the same telescope when different magnifying powers are employed, I generally use the following simple method. The telescopes are placed at eight or ten feet distant from a window, with their eye-ends parallel to each other, or at the same distance from the window. Looking at a distant object, I fix upon a portion of it whose magnified image will appear to fill exactly two or three panes of the window; then, putting on a different power, or looking through another telescope, I observe the same object, and mark exactly the extent of its image on the window-panes, and compare the extent of the one image with the other. Suppose, for example, that the one telescope has been previously found to magnify ninety times, and that the image of the object fixed upon exactly fills three panes of the window, and that with the other power or the other telescope the image fills exactly two panes, then the magnifying power is equal to two-thirds of the former, or sixty times; and were it to fill only one pane, the power would be about thirty times. A more correct method is to place at one side of the window a narrow board two or three feet long, divided into fifteen or twenty equal parts, and observe how many of these parts appear to be covered by the respective image of the different telescopes. Suppose, in the one case, ten divisions to be covered by the image in a telescope magnifying ninety times, and that the image of the same object in another telescope measures six divisions, then its power is found by the following proportion: 10 : 90 : : 6 : 54; that is, this telescope magnifies 54 times.

Another mode which I have used for determining, to a near approximation, the powers of telescopes, is as follows: Endeavour to find the focus of a single lens which is exactly equivalent to the magnifying power of the eyepiece, whether the Huygenian or the common terrestrial eyepiece. This may be done by taking small lens, and using it as an object-glass to the eyepiece. Looking through the eyepiece to a window and holding the lens at a proper distance, observe whether the image of one of the panes exactly coincides with the pane as seen by the naked eye; if it does, then the magnifying power of the eyepiece is equal to that of the lens. If the lens be half an inch in focal length, the eyepiece will produce the same magnifying power

as a single lens when used as an eyeglass to the telescope, and the magnifying power will then be found by dividing the focal distance of the object-glass by that of the eyeglass; but if the image of the pane of glass does not exactly coincide with the pane as seen by the other eye, then proportional parts may be taken by observing the divisions of such a board as described above, or we may try lenses of different focal distances. Suppose, for example, that a lens two inches focal length had been used, and that the image of a pane covered exactly the space of two panes, the power of the eyepiece is then equal to that of a single lens of one inch focal distance.

The following is another mode depending on the same general principle. If a slip of writing-paper one inch long, or a disk of the same material one inch in diameter, be placed on a black ground at from 30 to 50 yards' distance from the object-end of the telescope, and a staff painted white, and divided into inches and parts by strong black lines, be placed vertically near the said paper or disk, the eye that is directed through the telescope when adjusted for vision will see the magnified disk, and the other eye, looking along the outside of the telescope, will observe the number of inches and parts that the disk projected on it will just cover, and as many inches as are thus covered will indicate the magnifying power of the telescope, at the distance for which it is adjusted for distinct vision. The solar power, or powers for very distant objects, may be obtained by the following proportion: As the terrestrial focal length at the given distance is to the solar focal length, so is the terrestrial to the solar power. For example, a disk of white paper one inch in diameter was placed on a black board, and suspended on a wall contiguous to a vertical black staff that was graduated into inches by strong white lines, at a distance of 33 yards $2\frac{1}{2}$ feet, and when the adjustment for vision was made with a 42 inch telescope, the left eye of the observer viewed the disk projected on the staff, while the right eye observed that the enlarged image of the disk covered just $58\frac{1}{2}$ inches on the staff, which number was the measure of the magnifying power at the distance answering to 33 yards $2\frac{1}{2}$ feet, which in this case exceeded the solar focus by an inch and a half. Then, according to the above analogy, we have, as 43.5 : 42 : : 58.5 : 56.5 nearly. Hence the magnifying power due to the solar focal length of the telescope in question is 56.5, and the distance, 33 yards $2\frac{1}{2}$ feet, is that which corresponds to an elongation of the solar focal distance an inch and a half.* If we multiply the terrestrial and the solar focal distances together, and divide the product by their difference, we shall again obtain the distance of the terrestrial object from the telescope. Thus, $\frac{43.5 + 42}{1.5} = 1218$ inches $= 101.5$ feet, or 33 yards $2\frac{1}{2}$ feet.

The magnifying power of a telescope is also determined by measuring the image which the object-glass or the large speculum of a telescope forms at its solar focus. This is accomplished by means of an instrument called a *Dynameter*. This apparatus consists of a strip of mother-of-pearl, marked with equal divisions, from the $\frac{1}{100}$th to the $\frac{1}{1000}$th of an inch apart, according to the accuracy required. This measure is attached to a magnifying lens in its focus, in order to make the small divisions more apparent. When the power of a telescope is required, the person must measure the clear aperture of the object-glass; then, holding the pearl *dynameter* next the eyeglass, let him observe how many divisions the small circle of light occupies when the instrument is directed to a bright object; then, by dividing the diameter of the object-glass by the diameter of this circle of light, the power will be obtained.† The most accurate instrument of this kind is the *Double Image Dynameter* invented by Ramsden, and another on the same principle now made by Dollond, a particular description of which may be found in Dr. Pearson's "Introduction to Practical Astronomy." The advantage attending these dynameters is, that they do not require any knowledge of the thickness and focal lengths of any of the lenses employed in a telescope, nor yet of their number and relative positions; neither does it make any difference whether the construction be refracting or reflecting, direct or inverting. One operation includes the result arising from the most complicated construction.

I shall only mention further the following method of discovering the magnifying power, which is founded on the same general principle as alluded to above. Let the telescope be placed in such a position opposite the sun that the rays of light may fall perpendicularly on the object-glass; the pencil of rays may be received on a piece of paper, and its diameter measured. Then, as the diameter of the pencil of rays is to that of the object-glass, so is the magnifying power of the telescope.

8. *On Cleaning the Lenses of Telescopes.*—It is necessary, in order to distinct vision, that the glasses, particularly the eyeglasses of telescopes, be kept perfectly clean, free of damp, dust, or whatever may impede the transmission of the rays of light; but great caution ought to be exercised in the wiping of them, as they are apt to be scratched or

* Pearson's "Practical Astronomy," vol. ii.

† The mother-of-pearl dynameter may be purchased for about twelve shillings. See fig. 57, *a*, *b*, *c*, p. 95

otherwise injured by a rough and incautious mode of cleaning them. They should never be attempted to be wiped unless they really require it; and in this case, they should be wiped carefully and gently with a piece of new and soft lamb's-skin leather; if this be not at hand, a piece of fine silk paper, or fine clean linen may be used as a substitute. The lens which requires to be most particularly attended to is the second glass from the eye, or the field-glass; for if any dust or other impediment be found upon this glass, it is always distinctly seen, being magnified by the glass next the eye. The next glass which requires attention is the fourth from the eye, or that which is next the object. Unless the glass next the eye be very dusty, a few small spots or grains of dust are seldom perceptible. The object-glass of an achromatic should seldom be touched unless damp adheres to it. Care should be taken never to use pocket-handkerchiefs or dirty rags for wiping lenses. From the frequent use of such articles, the glasses of seamen's telescopes get dimmed and scratched in the course of a few years. If the glasses be exceedingly dirty, and if greasy substances are attached to them, they may be soaked in spirits and water, and afterward carefully wiped. In replacing the glasses in their socket, care should be taken not to touch the surfaces with the fingers, as they would be dimmed with the perspiration: they should be taken hold of by the edges only, and carefully screwed into the same cells from which they were taken.

## ON MEGALASCOPES, OR TELESCOPES FOR VIEWING VERY NEAR OBJECTS.

It appears to have been almost overlooked by opticians and others, that telescopes may be constructed so as to exhibit a beautiful and minute view of very near objects, and to produce even a microscopic effect without the least alteration in the *arrangement* of the lenses of which they are composed. This object is effected simply by making the eye-tube of a telescope of such a length as to be capable of being drawn out twelve or thirteen inches beyond the point of distinct vision for distant objects. The telescope is then rendered capable of exhibiting with distinctness all kinds of objects, from the most distant to those which are placed within three or four feet of the instrument, or not nearer than double the focal distance of the object-glass. Our telescopes, however, are seldom or never fitted with tubes that slide further than an inch or two beyond the point of distinct vision for distant objects, although a tube of a longer size than usual, or an additional tube would cost but a trifling expense.

The following, among many others, are some of the objects on which I have tried many amusing experiments with telescopes fitted up with the long tubes to which I allude. The telescope to which I shall more particularly advert is an achromatic, mounted on a pedestal, having an object-glass about nineteen inches focal length, and $1\frac{5}{8}$ths of an inch in diameter, with magnifying powers for distant objects of thirteen and twenty times. When this instrument is directed to a miniature portrait $3\frac{1}{2}$ inches in length, placed in a good light, at the distance of about eight or ten feet, it appears as large as an oil-painting four or five feet long, and represents the individual as large as life. The features of the face appear to stand out in bold relief; and perhaps there is no representation of the human figure that more resembles the living prototype than in this exhibition provided the miniature is finely executed. In this case the tube requires to be pulled out four or five inches from the point of distinct vision for distant objects, and consequently the magnifying power is proportionally increased. Another class of objects to which such a telescope may be applied is *Perspective Prints*, either of public buildings, streets, or landscapes. When viewed in this way they present a panoramic appearance, and seem nearly as natural as life, just in the same manner as they appear in the Optical Diagonal Machine, or when reflected in a large concave mirror, with this advantage, that while in these instruments the left-hand side of the print appears where the right should be, the objects seen through the telescope appear exactly in their natural position. In this case, however, the telescope should have a small magnifying power, not exceeding five or six times, so as to take in the whole of the landscape. If an astronomical eye-piece be used, the print will require to be inverted.

Other kinds of objects which may be viewed with this instrument are trees, flowers, and other objects in gardens immediately adjacent to the apartment in which we make our observations. In this way we may obtain a distinct view of a variety of rural objects, which we cannot easily approach, such as the buds and blossoms on the tops of trees, and the insects with which they may be infested. There are certain objects on which the telescope may be made to produce a powerful microscopical effect, such as the more delicate and beautiful kinds of flowers, the leaves of trees, and similar objects. In viewing such objects, the telescope may be brought within little more than double the focal distance of the object-glass from the objects to be viewed, and then the magnifying power is very considerably increased. A nosegay composed of a variety

of delicate flowers, and even a single flower, such as the sea pink, makes a splendid appearance in this way. A peacock's feather, or even the fibres on a common quill, appear very beautiful when placed in a proper light. The leaves of trees, particularly the leaf of the plane-tree, when placed against a window-pane, so that the light may shine through them, appear, in all their internal ramifications, more distinct, beautiful, and interesting, than when viewed in any other way; and in such views a large portion of the object is at once exhibited to the eye. In this case, the eyepiece of such a telescope as that alluded to requires to be drawn out twelve or fourteen inches beyond the point of distinct vision for objects at a distance, and the distance between these near objects and the object-end of the telescope is only about 3½ feet.

A telescope having a diagonal eyepiece presents a very pleasant view of near objects in this manner. With an instrument of this kind I have frequently viewed the larger kind of small objects alluded to above, such as the leaves of shrubs and trees, flowers consisting of a variety of parts, the fibres of a peacock's feather, and similar objects. In this case, the object-glass of the instrument, which is 10½ inches focal length, was brought within 22 inches of the object, and the eye looked down upon it in the same manner as when we view objects in a compound microscope. A common pocket achromatic telescope may be used for the purposes now stated, provided the tube in the eyepiece containing the two lenses next the object be taken out, in which case the two glasses next the eye form an astronomical eyepiece, and the tubes may be drawn out five or six inches beyond the focal point for distant objects, and will produce distinct vision for objects not further distant than about 20 or 24 inches; but in this case, the objects to be viewed must be inverted, in order that they may be seen in their natural positions when viewed through the instrument. Telescopes of a large size and high magnifying powers may likewise be used with advantage for viewing very near objects in gardens adjacent to the room in which the instruments are placed, provided the sliding-tube next the eye has a range of two or three inches beyond the point of vision for distant objects. In this case, a magnifying power of 100 times on a 3½ or a five feet achromatic produces a very pleasant effect. In making the observations to which I have now alluded, it is requisite in order to distinct vision, and to obtain a pleasing view of the objects, that the instrument should be placed on a pedestal, and capable of motion in every direction. The adjustment for distinct vision may be made either by the sliding-tube, or by removing the telescope nearer to or further from the object.

### REFLECTIONS ON LIGHT AND VISION, AND ON THE NATURE AND UTILITY OF TELESCOPES.

Light is one of the most wonderful and beneficial, and, at the same time, one of the most mysterious agents in the material creation. Though the sun from which it flows to this part of our system is nearly a hundred millions of miles from our globe, yet we perceive it as evidently, and feel its influence as powerfully, as if it emanated from no higher a region than the clouds. It supplies life and comfort to our physical system, and without its influence and operations on the various objects around us, we could scarcely subsist and participate of enjoyment for a single hour. It is diffused around us on every hand from its fountain, the sun; and even the stars, though at a distance hundreds of thousands of times greater than that of the solar orb, transmit to our distant region a portion of this element. It gives beauty and fertility to the earth, it supports the vegetable and animal tribes, and is connected with the various motions which are going forward throughout the system of the universe. It unfolds to us the whole scenery of external nature; the lofty mountains and the expansive plains, the majestic rivers and the mighty ocean; the trees, the flowers, the crystal streams, and the vast canopy of the sky, adorned with ten thousands of shining orbs. In short, there is scarcely an object within the range of our contemplation but what is exhibited to our understanding through the medium of light, or at least bears a certain relation to this enlivening and universal agent. When we consider the extreme minuteness of the rays of light, their inconceivable velocity, the invariable laws by which they act upon all bodies, the multifarious phenomena produced by their inflections, refractions, and reflections, while their original properties remain the same; the endless variety of colours they produce on every part of our terrestrial creation, and the facility with which millions of rays pass through the smallest apertures, and pervade substances of great density, while every ray passes forward in the crowd without disturbing another, and produces its own specific impression, we cannot but regard this element as the most wonderful, astonishing, and delightful part of the material creation. When we consider the admirable beauties and the exquisite pleasures of which light is the essential source, and how much its nature is still involved in mystery, notwithstanding the profound inves-

tigations of modern philosophers, we may well exclaim with the poet,

"How then shall I attempt to sing of HIM
Who, light himself, in uncreated light
Invested deep, dwells awfully retired
From mortal eye or angel's purer ken;
Whose single smile has, from the first of time,
Filled, overflowing, all yon lamps of heaven,
That beam for ever through the boundless sky."
THOMSON.

The eye is the instrument by which we perceive the beautiful and multifarious effects of this universal agent. Its delicate and complicated structure; its diversified muscles; its coats and membranes; its different humours, possessed of different refractive powers; and the various contrivances for performing and regulating its external and internal motions, so as to accomplish the ends intended, clearly demonstrate this organ to be a masterpiece of Divine mechanism—the workmanship of Him whose intelligence surpasses conception, and whose wisdom is unsearchable. "Our sight," says Addison, "is the most perfect and delightful of all our senses. It fills the mind with the largest variety of ideas, converses with its objects at the greatest distance, and continues the longest in action, without being tired or satiated with its proper enjoyments. The sense of feeling can indeed give us a motion of extension, shape, and all other ideas that enter the eye except colours; but, at the same time, it is very much strained, and confined in its operation to the number, bulk, and distance of its particular objects. Our sight seems designed to supply all these defects, and may be considered as a more delicate and diffusive kind of touch, that spreads itself over an infinite multitude of bodies, comprehends the largest figures, and brings into our reach some of the more remote parts of the universe."

Could we suppose an order of beings endued with every human faculty but that of sight, it would appear incredible to such beings, accustomed only to the slow information of touch, that by the addition of an organ consisting of a ball and socket, of an inch in diameter, they might be enabled, in an instant of time, without changing their place, to perceive the disposition of a whole army, the order of a battle, the figure of a magnificent palace, or all the variety of a landscape. If a man were by feeling to find out the figure of the Peak of Teneriffe, or even of St. Peter's Church at Rome, it would be the work of a lifetime. It would appear still more incredible to such beings as we have supposed, if they were informed of the discoveries which may be made by this little organ in things far beyond the reach of any other sense, that by means of it we can find our way in the pathless ocean; that we can traverse the globe of the earth, determine its figure and dimensions, and delineate every region of it; yea, that we can measure the planetary orbs, and make discoveries in the sphere of the fixed stars. And if they were further informed that, by means of this same organ, we can perceive the tempers and dispositions, the passions and affections of our fellow-creatures, even when they want most to conceal them; that when the tongue is taught most artfully to lie and dissemble, the hypocrisy should appear in the countenance to a discerning eye; and that by this organ we can often perceive what is straight and what crooked in the mind as well as in the body, would it not appear still more astonishing to beings such as we have now supposed?*

Notwithstanding these wonderful properties of the organ of vision, the eye, when unassisted by art, is comparatively limited in the range of its powers. It cannot ascertain the existence of certain objects at the distance of three or four miles, nor perceive what is going forward in nature or art beyond such a limit. By its natural powers we perceive the moon to be a globe about half a degree in diameter, and diversified with two or three dusky spots, and that the sun is a luminous body of apparently the same size; that the planets are luminous points, and that about a thousand stars exist in the visible canopy of the sky. But the ten thousandth part of those luminaries which are within the reach of human vision can never be seen by the unassisted eye. Here the TELESCOPE interposes, and adds a new power to the organ of vision, by which it is enabled to extend its views to regions of space immeasurably distant, and to objects, the number and magnitude of which could never otherwise have been surmised by the human imagination. By its aid we obtain a sensible demonstration that space is boundless; that the universe is replenished with innumerable suns and worlds; that the remotest regions of immensity, immeasurably beyond the limits of unassisted vision, display the energies of Creating Power; and that the empire of the Creator extends far beyond what eye hath seen or the human imagination can conceive.

The telescope is an instrument of a much more wonderful nature than what most people are apt to imagine. However popular such instruments now are, and however common a circumstance it is to contemplate objects at a great distance which the naked eye cannot discern, yet, prior to their invention and improvement, it would have appeared a thing most mysterious, if not impossible, that objects at the distance of ten miles could be made to appear as if within a few yards of us, and that

* Reid's Inquiry into the Human Mind, chap. iv

some of the heavenly bodies could be seen as distinctly as if we had been transported by some superior power hundreds of millions of miles beyond the bounds of our terrestrial habitation. Who could ever have imagined, reasoning *a priori*, that the refraction of light in glass—the same power by which a straight rod appears crooked in water, by which vision is variously distorted, and by which we are liable to innumerable deceptions—that that same power or law of nature, by the operation of which the objects in a landscape appear distorted when seen through certain panes of glass in our windows, that that power should ever be so modified and directed as to extend the boundaries of vision, and enable us clearly to distinguish scenes and objects at a distance a thousand times beyond the natural limits of our visual organs? Yet such are the discoveries which science has achieved, such the powers it has brought to light, that by glasses ground into different forms, and properly adapted to each other, we are enabled, as it were, to contract the boundaries of space, to penetrate into the most distant regions, and to bring within the reach of our knowledge the most sublime objects in the universe.

When Pliny declared in reference to Hipparchus, the ancient astronomer, "*Ausus rem Deo improbam annumerare posteris stellas*," that "he dared to enumerate the stars for posterity, an undertaking forbidden by God," what would that natural historian have said had it been foretold that in less than 1600 years afterward a man would arise who should enable posterity to perceive and to enumerate ten times more new stars than Hipparchus ever beheld—who should point out higher mountains on the moon than on the earth—who should discover dark spots as large as our globe in the sun, the fountain of light—who should descry four moons revolving in different periods of time around the planet Jupiter, and could show to surrounding senators the varying phases of Venus? and that another would soon after arise who should point out a double ring of six hundred thousand miles in circumference revolving around the planet Saturn, and ten hundreds of thousands of stars which neither Hipparchus nor any of the ancient astronomers could ever descry? Yet these are only a small portion of the discoveries made by Galileo and Herschel by means of the telescope. Had any one prophetically informed Archimedes, the celebrated geometrician of Syracuse, that vision would, in after ages, be thus wonderfully assisted by art; and, further, that one manner of improving vision would be to place a dark, *opaque* body directly between the object and the eye; and that another method would be, not to look at the object, but to keep the eye quite in a different, and even in an *opposite* direction, or to stand with the back directly opposed to it, and to behold all the parts of it, invisible to the naked eye, most distinctly in this way, he would doubtless have considered the prophet as an enthusiastic fool or a raving madman. Yet these things have been realized in modern times in the fullest extent. In the Gregorian reflecting telescope, an opaque body, namely, the small speculum near the end of the tube, interposes *directly* between the eye and the object. In the Newtonian reflector, and in the diagonal eyepieces formerly described, the eye is directed in a line at right angles to the object, or a deviation of 90 degrees from the direct line of vision. In Herschel's large telescopes, and in the *Aerial Reflector* formerly described, (in p. 112-117,) the back is turned to the object, and the eye in an opposite direction.

These circumstances should teach us humility and a becoming diffidence in our own powers; and they should admonish us not to be too dogmatical or peremptory in affirming what is possible or impossible in regard either to nature or art, or to the operations of the Divine Being. Art has accomplished, in modern times, achievements in regard to locomotion, marine and aerial navigation, the improvement of vision, the separation and combinations of invisible gases, and numerous other objects, of which the men of former ages could not have formed the least conception; and even yet we can set no boundaries to the future discoveries of science and the improvements of art, but have every reason to indulge the hope that, in the ages to come, scenes of Divine mechanism in the system of nature will be unfolded, and the effects of chemical and mechanical powers displayed, of which the human mind, in its present state of progress, cannot form the most imperfect idea. Such circumstances likewise should teach us not to reject any intimations which have been made to us in relation to the character, attributes, and dispensations of the Divine Being, and the moral revelations of his will given in the Sacred Records, because we are unable to comprehend every truth and to remove every difficulty which relates to the moral government of the Great Ruler of the universe; for if we meet with many circumstances in secular science, and even in the common operations of nature, which are difficult to comprehend—if even the construction of such telescopes as we now use would have appeared an incomprehensible mystery to ancient philosophers, we must expect to find difficulties almost insurmountable to such limited minds as ours in the eternal plans and moral arrangements of the "King Immortal and Invisible," as delineated only in their outlines in the

Sacred Oracles, particularly those which relate to the origin of physical and moral evil, the ultimate destiny of man, and the invisible realities of a future world.

The UTILITY of the telescope may be considered in relation to the following circumstances:

In the first place, it may be considered as an instrument or machine which virtually transports us to the distant regions of space. When we look at the moon through a telescope which magnifies 200 times, and survey its extensive plains, its lofty peaks, its circular ranges of mountains, throwing their deep shadows over the vales, its deep and rugged caverns, and all the other varieties which appear on the lunar surface, we behold such objects in the same manner as if we were standing at a point 238,800 miles from the earth in the direction of the moon, or only twelve hundred miles from that orb, reckoning its distance to be 240,000 miles. When we view the planet Saturn with a similar instrument, and obtain a view of its belts and satellites, and its magnificent rings, we are transported, as it were, through regions of space to a point in the heavens more than *nine hundred millions of miles* from the surface of our globe, and contemplate those august objects as if we were placed within five millions of miles of the surface of that planet.* Although a supernatural power sufficient to carry us in such a celestial journey a thousand miles every day were exerted, it would require more than two thousand four hundred and sixty years before we could arrive at such a distant position; yet the telescope, in a few moments, transports our visual powers to that far distant point of space. When we view with such an instrument the minute and very distant clusters of stars in the Milky Way, we are carried, in effect, through the regions of space to the distance of *five hundred thousand millions of miles* from the earth; for we behold those luminaries through the telescope nearly as if they were actually viewed from such a distant point in the spaces of the firmament. These stars cannot be conceived as less than *a hundred billions* of miles from our globe, and the instrument we have supposed brings them within the two hundredth part of this distance. Suppose we were carried forward by a rapid motion towards this point at the rate of a thousand miles *every hour*, it would require more than *fifty-seven thousand years* before we could reach that very distant station in space to which the telescope, *in effect*, transports us: so that this instrument is far more efficient in opening to our view the scenes of the universe, than if we were invested with powers of locomotion to carry us through the regions of space with the rapidity of a cannon ball at its utmost velocity; and all the while we may sit at ease in our terrestrial apartments.

In the next place, the telescope has been *the means of enlarging our views of the sublime scenes of creation* more than any other instrument which art has contrived. Before the invention of this instrument, the universe was generally conceived as circumscribed within very narrow limits. The earth was considered as one of the largest bodies in creation; the planets were viewed as bodies of a far less size than what they are now found to be; no bodies similar to our moon were suspected as revolving around any of them; and the stars were supposed to be little more than a number of brilliant lamps hung up to emit a few glimmering rays, and to adorn the canopy of our earthly habitation. Such a wonderful phenomenon as the ring of Saturn was never once suspected, and the sun was considered as only a large ball of fire. It was suspected, indeed, that the moon was diversified with mountains and vales, and that it might possibly be a habitable world; but nothing certainly could be determined on this point, on account ot the limited nature of unassisted vision. But the telescope has been the means of expanding our views of the august scenes of creation to an almost unlimited extent: it has withdrawn the vail which formerly interposed to intercept our view of the distant glories of the sky: it has brought to light five new planetary bodies, unknown to former astronomers, one of which is more than eighty times larger than the earth, and seventeen *secondary* planets which revolve around the primary: it has expanded the dimensions of the solar system to double the extent which was formerly supposed: it has enabled us to descry hundreds of comets which would otherwise have escaped our unassisted vision, and to determine some of their trajectories and periods of revolution: it has explored the profundities of the Milky Way, and enabled us to perceive hundreds of thousands of those splendid orbs, where scarcely one is visible to the naked eye: it has laid open to our view thousands of *Nebulæ*, of various descriptions, dispersed through different regions of the firmament, many of them

* The distance of Saturn from the sun is 906,000,000 of miles; it is sometimes nearer to, and at other times further from the earth, according as it is near the point of its opposition to, or conjunction with, the sun. If this number be divided by 200, the supposed magnifying power of the telescope, the quotient is 4,530,000, which expresses the distance in miles at which it enables us to contemplate this planet. If this number be subtracted from 906,000,000, the remainder is 901,470,000, which expresses the number of miles from the earth at which we are supposed to view Saturn with such an instrument.

containing thousands of separate stars: it has directed our investigations to thousands of double, treble, and multiple stars—suns revolving around suns, and systems around systems; and has enabled us to determine some of the periods of their revolutions: it has demonstrated the immense distances of the starry orbs from our globe, and their consequent magnitudes, since it shows us that, having brought them nearer to our view by several hundreds or thousands of times, they still appear only as so many shining *points:* it has enabled us to perceive that mighty changes are going forward throughout the regions of immensity—new stars appearing, and others removed from our view, and motions of incomprehensible velocity carrying forward those magnificent orbs through the spaces of the firmament: in short, it has opened a vista to regions of space so immeasurably distant, that a cannon ball impelled with its greatest velocity would not reach tracts of creation so remote in two thousand millions of years; and even light itself, the swiftest body in nature, would require more than a thousand years before it could traverse this mighty interval. It has thus laid a foundation for our acquiring an approximate idea of the infinity of space, and for obtaining a glimpse of the far distant scenes of creation, and the immense extent of the universe.

Again, the telescope, in consequence of the discoveries it has enabled us to make, has tended *to amplify our conceptions of the attributes and the empire of the Deity.* The amplitude of our conceptions of the Divine Being bears a certain proportion to the expansion of our views in regard to his works of creation, and the operations he is incessantly carrying forward throughout the universe. If our views of the works of God, and of the manifestations he has given of himself to his intelligent creatures, be circumscribed to a narrow sphere, as to a parish, a province, a kingdom, or a single world, our conceptions of that Great Being will be proportionably limited; for it is chiefly from the manifestation of God in the material creation that our ideas of his power, his wisdom, and his other natural attributes are derived. But in proportion to the ample range or prospect we are enabled to take of the operations of the Most High, will be our conceptions of his character, attributes, and agency. Now the telescope, more than any other invention of man, has tended to open to our view the most magnificent and extensive prospects of the works of God; it has led us to ascertain that, within the limits of the solar system, there are bodies which, taken together, comprise a mass of matter nearly two thousand five hundred times greater than that of the earth; that these bodies are all constituted and arranged in such a manner as to fit them for being habitable worlds; and that the sun, the centre of this system, is five hundred times larger than the whole. But, far beyond the limits of this system, it has presented to our view a universe beyond the grasp of finite intelligences, and to which human imagination can assign no boundaries: it has enabled us to descry suns clustering behind suns, rising to view in boundless perspective, in proportion to the extent of its magnifying and illuminating powers, the numbers of which are to be estimated, not merely by thousands, and tens of thousands, and hundreds of thousands, but by scores of *millions;* leaving us no room to doubt that hundreds of millions more beyond the utmost limits of human vision, even when assisted by art, lie hid from mortal view in the unexplored and unexplorable regions of immensity.

Here, then, we are presented with a scene which gives us a display of *Omnipotent Power* which no other objects can unfold, and which, without the aid of the telescope, we should never have beheld; a scene which expands our conceptions of the Divine Being to an extent which the men of former generations could never have anticipated; a scene which enables us to form an approximate idea of Him who is the "King Eternal, Immortal, and Invisible," who "created all worlds, and for whose pleasure they are and were created." Here we behold the operations of a Being whose power is illimitable and uncontrollable, and which far transcends the comprehension of the highest created intelligences; a power, displayed not only in the vast extension of material existence, and the countless number of mighty globes which the universe contains, but in the astonishingly *rapid motions* with which myriads of them are carried along through the immeasurable spaces of creation, some of those magnificent orbs moving with a velocity of one hundred and seventy thousand miles an hour. Here, likewise, we have a display of the infinite *wisdom* and intelligence of the Divine Mind, in the harmony and order with which all the mighty movements of the universe are conducted; in proportionating the magnitudes, motions, and distances of the planetary worlds; in the nice adjustment of the projectile velocity to the attractive power; in the constant proportion between the times of the periodical revolution of the planets and the cubes of their mean distances; in the *distances* of the several planets from the central body of the system, compared with their respective *densities;* and in the constancy and regularity of their motions, and the exactness with which they accomplish their destined rounds—all which

circumstances evidently show that He who contrived the universe is "the only wise God," who is "wonderful in counsel and excellent in working." Here, in fine, is a display of *boundless benevolence;* for we cannot suppose, for a moment, that so many myriads of magnificent globes, fitted to be the centres of a countless number of mighty worlds, should be nothing else than barren wastes, without the least relation to intelligent existence; and if they are peopled with intellectual beings of various orders, how vast must be their numbers, and how overflowing that Divine Beneficence which has provided for them all every thing requisite to their existence and happiness.

In these discoveries of the telescope we obtain a glimpse of the grandeur and the unlimited extent of God's universal empire. To this empire no boundaries can be perceived. The larger and the more powerful our telescopes are, the further are we enabled to penetrate into those distant and unknown regions; and however far we penetrate into the abyss of space, new objects of wonder and magnificence still continue rising to our view, affording the strongest presumption that, were we to penetrate ten thousand times further into those remote spaces of immensity, new suns, and systems, and worlds would be disclosed to our view. Over all this vast assemblage of material existence, and over all the sensitive and intellectual beings it contains, God eternally and unchangeably presides; and the minutest movements, either of the physical or the intelligent system, throughout every department of those vast dominions, are at every moment "naked and open" to his omniscient eye. What *boundless intelligence* is implied in the *superintendence* and *arrangement* of the affairs of such an unlimited empire! and what a lofty and expansive idea does it convey of Him who sits on the throne of Universal Nature, and whose greatness is unsearchable! But without the aid of the telescopic tube we could not have formed such ample conceptions of the greatness, either of the Eternal Creator himself, or of the universe which he hath brought into existence.

Besides the above, the following uses of the telescope, in relation to science and common life, may be shortly noticed:

In the business of astronomy, scarcely any thing can be done with accuracy without the assistance of the telescope. 1. It enables the astronomer to determine with precision *the transits of the planets and stars* across the meridian; and on the accuracy with which these transits are obtained, a variety of important conclusions and calculations depend. The computation of astronomical and nautical tables for aiding the navigator in his voyages round the globe, and facilitating his calculations of latitude and longitude, is derived from observations made by the telescope, without the use of which instrument they cannot be made with precision. 2. The *apparent diameters of the planets* can only be measured by means of this instrument, furnished with a micrometer. By the naked eye no accurate measurements of the diameters of these bodies can be taken; and without knowing their apparent diameters in minutes or seconds, their real bulk cannot be determined, even although their exact distances be known. The differences, too, between the polar and equatorial diameters cannot be ascertained without observations made by powerful telescopes. For example, the equatorial diameter of Jupiter is found to be in proportion to the polar as 14 to 13, that is, the equatorial is more than 6000 miles longer than the polar diameter, which could never have been determined by observations made by the naked eye. 3. The *parallaxes* of the heavenly bodies can only be accurately ascertained by the telescope; and it is only from the knowledge of their parallaxes that their distances from the earth or from the sun can be determined. In the case of the fixed stars, nothing of the nature of a parallax could ever be expected to be found without the aid of a telescope. It was by searching for the parallax of a certain fixed star that the important fact of the *Aberration of Light* was discovered. The observations for this purpose were made by means of a telescope 24 feet long, fixed in a certain position. 4. The motions and revolutionary periods of *Sidereal Systems* can only be determined by observations made by telescopes of great magnifying and illuminating powers. Without a telescope the small stars which accompany double or treble stars cannot be perceived, and much less their motions or variation of their relative positions. Before the invention of the telescope, such phenomena, now deemed so wonderful and interesting, could never have been surmised. 5. The accurate determination of the longitude of places on the earth's surface is ascertained by the telescope, by observing with this instrument the immersions and emersions of the satellites of Jupiter. From such observations, with the aid of a chronometer, and having the time at any known place, the situation of any unknown place is easily determined. But the eclipses of Jupiter's moons can be perceived only by telescopic instruments of considerable power. 6. By means of a telescope with cross hairs in the focus of the eyeglass, and attached to a quadrant, the altitude of the sun or of a star, particularly the pole star, may be most accurately taken, and from such observations the *latitude* of the place may be readily and accurately deduced.

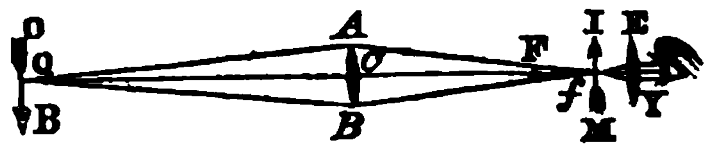
Again, in the *Surveying of Land*, the telescope is particularly useful; and for this purpose it is mounted on a stand with a horizontal and vertical motion, pointing out by divisions the degrees and minutes of inclination of the instrument. For the more accurate reading of these divisions, the two limbs are furnished with a nonius, or *Vernier's Scale*. The object here is to take the angular distances between distant objects on a plane truly horizontal, or else the angular elevation or depression of objects above or below the plane of the horizon. In order to obtain either of those kinds of angles to a requisite degree of exactness, it is necessary that the surveyor should have as clear and distinct a view as possible of the objects, or station-staves, which he fixes up for his purpose, that he may with the greater certainty determine the point of the object which exactly corresponds with the line he is taking. Now, as such objects are generally at too great a distance for the surveyor to be able to distinguish with the naked eye, he takes the assistance of the telescope, by which he obtains, 1, a distinct view of the object to which his attention is directed, and, 2, he is enabled to determine the precise point of the object aimed at by means of the cross hairs in the focus of the eyeglass. A telescope mounted for this purpose is called a *Theodolite*, which is derived from two Greek words, ϑεομαι, *to see*, and οδος, *the way* or *distance*.

In the next place, the telescope is an instrument of special importance in the conducting of *Telegraphs*, and in the conveyance of *signals* of all descriptions. Without its assistance telegraphic despatches could not be conveyed with accuracy to any considerable distance, nor in quadruple the time in which they are now communicated, and the different stations would need to be exceedingly numerous; but, by the assistance of the telescope, information may be communicated, by a series of telegraphs, with great rapidity. Twenty-seven telegraphs convey information from Paris to Calais, a distance of 160 miles, in three minutes; twenty-two from Paris to Lisle in two minutes; forty-six from Strasburg to Paris in four and a half minutes; and eighty from Paris to Brest in ten minutes. In many other cases which occur both on land and sea, the telescope is essentially requisite for descrying signals. The *Bell-Rock Lighthouse*, for example, is situated twelve miles from Arbroath, and from every other portion of land, so that the naked eye could not discern any signal which the keepers of that light could have it in their power to make; but by means of a large telescope in the station-house in Arbroath, the hoisting of a ball every morning at 9 A.M., which indicates that "All is well," may be distinctly recognized.

Many other uses of this instrument, in the ordinary transactions of life, will readily occur to the reader, and therefore I shall only mention the following purpose to which it may be applied, namely,

*To measure the Distance of an Object from one Station.*—This depends upon the increase of the focal distance of the telescope in the case of near objects. Look through a telescope at the object whose distance is required, and adjust the focus till it appear quite distinct; then slide in the drawer till the object begins to be obscure, and mark that place of the tube precisely; next draw out the tube till the object begins to be again obscured, and then make another mark as before; then take the middle point between these two marks, and that will be the point where the image of the object is formed most distinctly, which is to be nicely measured from the object-lens, and compared with the solar focus of the lens or telescope, so as to ascertain their difference. And the rule for finding the distance is, as the difference between the focal distance of the object and the solar focal distance is to the solar focal distance, so is the focal distance of the object to its true distance from the object-lens. An example will render this matter more perspicuous:

Fig. 84.




Let $A\ B$ (fig. 84) be the object-lens, $E\ Y$ the eyeglass, $F\ C$ the radius, or focus of the lens $A\ B$, and $C\ f$ the focal distance of the object $O\ B$, whose distance is to be measured. Now suppose $C\ F = 48$ inches, or four feet, and that we find by the above method that $C\ f$ is 50 inches, then $F\ f$ is two inches; and the analogy is, as $F\ f = 2$ is to $C\ F = 48$, so is $C\ f = 50$ to $C\ Q = 1200$ inches, or 100 feet. Again, suppose $C\ f = 49$ inches, then will $F\ f = 1$ inch; and the proportion is, $1 : 48 :: 49 : 2352 = Q\ C$, or 196 feet. A telescope of this focal length, however, will measure only small distances. But suppose $A\ B$ a lens whose solar focus is 12 feet, or 144 inches, and that we find by the above method that $C\ f$, or the focal distance of the object, is 146 inches, then will $F\ f$ be two inches, and the proportion will be as $2 : 144 :: 146 : 21024$ inches, or 1752 feet = the distance $Q\ C$. If with such a large telescope we view an object $O\ B$, and find $F\ f$ but $\frac{1}{10}$th of an inch, this will give the distance of the object as 17,292 feet, or nearly $3\frac{1}{3}$d miles.

Since the difference between the radius of the object-lens and the focal distance of the object is so considerable as two inches in a tube of four feet, and more than twelve inches in one of twelve feet, a method might be contrived for determining the distance of near objects by the former, and more distant objects by the latter, by inspection only. This may be done by adjusting or drawing a spiral line round the drawer or tube through the *two-inch space* in the small telescope, and by calculation graduate it for every 100 feet and the intermediate inches, and then, at the same time we view an object, we may see its distance on the tube. In making such experiments, a common object-glass of a long focal length, and a single eyeglass, are all that is requisite, since the inverted appearance of the object can cause no great inconvenience.

## CHAPTER VII.

### *On the Method of Grinding and Polishing Optical Lenses and Specula.*

I ORIGINALLY intended to enter into particular details on this subject for the purpose of gratifying those mechanics and others who wish to amuse themselves by constructing telescopes and other optical instruments for their own use; but, having dwelt so long on the subject of telescopes in the preceding pages, I am constrained to confine myself to a very general sketch.

1. *To grind and polish Lenses for Eyeglasses, Microscopes, &c.*—First provide an upright spindle, at the bottom of which a pulley is fixed, which must be turned by a wheel by means of a cord and handle. At the top of the spindle make a screw the same as a lathe-spindle, on which you may screw chocks of different sizes, to which the brass tool in which the lens is to be ground may be fixed. Having fixed upon the breadth and focal length of the lens, and whether it is to be a plano or a double convex, take a piece of tin-plate or sheet copper, and with a pair of compasses draw an arch upon its surface, near one of its extremities, with a radius equal to the focal distance of the lens if intended to be double convex, or with half that distance if it is to be plano-convex. Remove with a file that part of the copper which is without the circular arch, and then a *convex* gauge is formed. With the same radius strike another arch, and having removed that part of the copper which is *within* it, a *concave* gauge will be obtained. The brass tool in which the glass is to be ground is then to be fixed upon a turning-lathe, and turned into a portion of a concave sphere, so as to correspond to the convex gauge. In order to obtain an accurate figure to the concave tool, a convex tool of exactly the same radius is generally formed, and they are ground one upon another with flour of emery, and when they exactly coincide they are fit for use. The convex tool will serve for grinding *concave* glasses of the same radius; and it should be occasionally ground in the concave tool to prevent it from altering its figure.

The next thing to be attended to is to prepare the piece of glass which is to be ground, by chipping it in a circular shape by means of a large pair of scissors, and removing the roughness from its edges by a common grindstone. The faces of the glass near the edges should likewise be ground on the grindstone till they nearly fit the concave gauge, by which the labour of grinding in the tool will be considerably saved. The next thing required is to prepare the emery for grinding, which is done in the following manner: Provide four or five clean earthen vessels: fill one of them with water, and put into it a pound or half a pound of fine emery, and stir it about with a stick; after which, let it stand three or four seconds, and then pour it into another vessel, which may stand about ten seconds: then pour it off again into the several vessels till the water is quite clear, and by this means emery of different degrees of fineness is obtained, which must be kept separate from each other, and worked in their proper order, beginning at the first, and working off all the marks of the grindstone; then take of the second, next of the third, &c., holding the glass upon the pan or tool with a light hand when it comes to be nearly fit for polishing. The glass, in this operation, should be cemented to a wooden handle by means of pitch or other strong cement. After the finest emery has been used, the roughness which remains may be taken away, and a slight polish given, by grinding the glass with pounded pumice-stone. Before proceeding to the polishing, the glass should be ground as smooth as possible, and all the scratches erased, otherwise the polishing will become a tedious process. The polishing is performed as follows: Tie a piece of linen rag or fine cloth about the tool, and with fine putty (calcined tin) or colcothar of vitriol (a very fine

powder, sometimes called the red oxide of iron,) moistened with water, continue the grinding motion, and in a short time there will be an excellent polish.

In order to grind lenses very accurately for the finest optical purposes, particularly object-glasses for telescopes, the concave tool is firmly fixed to a table or bench, and the glass wrought upon it by the hand with circular strokes, so that its centre may never go beyond the edges of the tool. For every six or seven circular strokes, the glass should receive two or three cross ones along the diameter of the tool, and in different directions; and, while the operation is going on, the convex tool should, at the end of five minutes, be wrought upon the concave one for a few seconds, in order to preserve the same curvature to the tools and to the glass. The finest polish is generally given in the following way: Cover the concave tool with a layer of pitch, hardened by the addition of a little rosin, to the thickness of $\frac{1}{16}$th of an inch; then, having taken a piece of thin writing paper, press it upon the surface of the pitch with the convex tool, and pull the paper quickly from the pitch before it has adhered to it; and if the surface of the pitch is marked every where with the lines of the paper, it will be truly spherical. If any paper remains on the surface of the pitch, it may be rubbed off by soap and water; and if the marks of the paper should not appear on any part of it, the operation must be repeated till the polisher or bed of pitch is accurately spherical. The glass is then to be wrought on the polisher by circular and cross strokes with the putty or colcothar till it has received a complete polish. When one side is finished, the glass must be separated from its handle by inserting the point of a knife between it and the pitch, and giving it a gentle stroke. The pitch which remains upon the glass may be removed by rubbing it with a little oil, or spirits of wine. The operation of polishing on cloth is slower, and the polish less perfect than on pitch; but it is a mode best fitted for those who have little experience, and who would be apt, in the first instance, to injure the figure of the lens by polishing it on a bed of pitch.

2. *On the Method of casting and grinding the Specula of Reflecting Telescopes.*—The first thing to be considered in the formation of reflecting telescopes is the *composition* of the metal of which the specula are made. The qualities required are, a sound, uniform metal, free from all microscopic pores, not liable to tarnish by absorption of moisture from the atmosphere—not so hard as to be incapable of taking a good figure and polish, nor so soft as to be easily scratched, and possessing a high reflecting power. Various compositions have been used for this purpose, of which the following are specimens: Take of good Swedish copper 32 ounces, and when melted, add 14½ ounces of grain tin to it; then, having taken off the scoria, cast it into an ingot. This metal must be a second time melted to cast a speculum; but it will fuse in this compound state with a small heat, and therefore will not calcine the tin to putty. It should be poured off as soon as it is melted, giving it no more heat than is absolutely necessary. The best method for giving the melted metal a good surface is this: the moment before it is poured off, throw into the crucible a spoonful of charcoal-dust; immediately after which, the metal must be stirred with a wooden spatula and poured into the moulds. The following is another composition somewhat similar: Take two parts of copper as pure as it is possible to procure: this must be melted in a crucible by itself; then put, in another crucible, one part of pure grain tin: when they are both melted, mix and stir them with a wooden spatula, keeping a good flux on the melted surface to prevent oxidation, and then pour the metal quickly into the moulds, which may be made of founder's loam.

The composition suggested, more than half a century ago, by the Rev. Mr. Edwards, has often been referred to with peculiar approbation. This gentleman took a great deal of pains to discover the best composition, and to give his metals a fine polish and the true parabolical figure. His telescopes were tried by Dr. Maskelyne, the astronomer royal, who found them greatly to excel in brightness, and to equal in other respects those made by the best artists. They showed a white object perfectly white, and all objects of their proper colour. He found, after trying various combinations, the following to be the best, namely, 32 ounces of copper, with 15 or 16 ounces of grain tin (according to the purity of the copper,) with the addition of one ounce of brass, one of silver, and one ounce of arsenic. This, he affirms, will form a metal capable, when polished in a proper manner, of reflecting more light than any other metal yet made public.

The Rev. J. Little, in his observations on this subject in the "Irish Transactions," proposes the following composition, which he found to answer the purpose better than any he had tried, namely, 32 parts of best bar copper, previously fluxed with the black flux of two parts tartar and one of nitre, four parts of brass, 16 parts of tin, and 1¼ of arsenic. If the metal be granulated, by pouring it, when first melted, into water, and then fused a second time, it will be less porous than at first. In this process, the chief object is to hit on the exact point of the saturation of the copper, &c., by the tin;

for if the latter be added in too great quantity, the metal will be dull coloured and soft; if too little, it will not attain the most perfect whiteness, and will certainly tarnish.*

When the metal is cast, and prepared by the common grindstone for receiving its proper figure, the gauges and grinding-tools are to be formed in the same manner as formerly described for lenses, with this difference, that the radius of the gauges must always be *double* the focal length of the speculum, as the focus of parallel rays by reflection is at one half the radius of concavity. In addition to the concave and convex tools, which should be only a little broader than the metal itself, a convex elliptical tool of lead and tin should be formed with the same radius, so that its transverse should be to its conjugate diameter as 10 to 9, the latter being exactly equal to the diameter of the metal. The grinding of the speculum is then to be commenced on this tool with coarse emery powder and water, when the roughness is taken off by moving the speculum across the tool in different directions, walking round the post on which the tool is fixed, holding the speculum by the wooden handle to which it is cemented; it is then to be wrought with great care on the convex brass tool, with circular and cross strokes, and with emery of different degrees—the concave tool being sometimes ground upon the convex one, to keep them all of the same radius—and when every scratch is removed from its surface, it will be fit for receiving the final polish.

When the metal is ready for polishing, the elliptical tool is to be covered with black pitch about $\frac{1}{10}$th of an inch thick, and the polisher formed in the same way as in the case of lenses ...er with the concave brass tool or ...h the metal itself. The colcothar of vitriol should then be triturated between two surfaces of glass, and a considerable quantity of it applied at first to the surface of the polisher. The speculum is then to be wrought in the usual way upon the polishing tool till it has received a brilliant lustre, taking care to use no more of the colcothar, if it can be avoided, and only a small quantity of it, if it should be found necessary. When the metal moves stiffly on the polisher, and the colcothar assumes a dark, muddy hue, the polish advances with great rapidity. The tool will then grow warm, and would probably stick to the speculum if its motion were discontinued for a moment. At this stage of the process, therefore, we must proceed with great caution, breathing continually on the polisher till the friction is so great as to retard the motion of the speculum. When this happens, the metal is to be slipped off the tool at one side, cleaned with soft leather, and placed in a tube for the purpose of trying its performance; and if the polishing has been conducted with care, it will be found to have a true *parabolic* figure.†

It was formerly the practice, before the speculum was brought to the polisher, to smooth it on a *bed of hones*, or a convex tool made of the best blue stone, such as clockmakers use in polishing their work, which was made one-fourth part larger than the metal which was to be ground upon it, and turned as true as possible to a gauge; but this tool is not generally considered as absolutely necessary, except when silver and brass enter into the composition of the metal, in order to remove the roughness which remains after grinding with the emery.

*To try the Figure of the Metal.*—In order to this, the speculum must be placed in the tube of the telescope for which it is intended, and at about 20 or 30 yards distant there should be put up a watch-paper, or similar object, on which there are some very fine strokes of an engraver. An annular kind of diagram should be made with card-paper, so as to cover a circular portion of the middle part of the speculum, between the hole and the circumference, equal in breadth to about one-eighth of its diameter. This paper ring should be fixed in the mouth of the telescope, and remain so during the whole experiment. There must likewise be two other circular pieces of card-paper cut out, of such sizes that one may cover the centre of the metal by completely filling the hole in the annular piece now described, and the other such a round piece as shall exactly fill the tube, and so broad as that the inner edge just touches the outward circumference of the middle annular piece. All these pieces together will completely shut up the mouth of the telescope. Let the round piece which covers the centre of the metal be removed, and adjust the instrument so that the image may be as sharp and distinct as possible; then replace the central piece, and remove the outside annular one, by which means the circumference only of the speculum will be exposed, and the image now formed will be from the rays reflected from the exterior side of the metal. If the two images formed by these two portions of the metal be perfectly sharp and equally distinct, the speculum is perfect and of the true parabolic curve; if, on the contrary, the image from the outside of the metal should not be distinct, and it should be necessary to bring the little speculum *nearer* by the screw, the metal is not yet brought to the parabolic figure; but if, in order to procure distinctness,

* *Irish Transactions*, vol. x. and Nicholson's Philosophical Journal, vol. xvi.

† Brewster's Appendix to "Ferguson's Lectures."

we be obliged to move the small speculum further off, then the figure of the great speculum has been carried beyond the parabolic, and has assumed the hyperbolic form.

*To adjust the Eyehole of Gregorian Reflectors.*—If there is only one eyeglass, then the distance of the small hole should be as nearly as possible equal to its focal length; but in the compound Huygenian eyepiece, the distance of the eyehole may be thus found: Multiply the difference between the focal distance of the glass next to the speculum, and the distance of the two eyeglasses, by the focal distance of the glass nearest the eye; divide the product by the sum of the focal distances of the two lenses, lessened by their distance, and the quotient will be the compound focal distance required. Thus, if the focal distance of the lens next the speculum be three inches, that of the lens next the eye one inch, and their distance two inches, then the compound focal distance from the eyeglass will be $\frac{3-2+1}{3+1-2}=\frac{1}{2}$ inch. The *diameter* of the eyehole is always equal to the quotient obtained by dividing the diameter of the great speculum by the magnifying power of the telescope. It is generally from $\frac{1}{25}$th to $\frac{1}{30}$th of an inch in diameter. It is necessary, in many cases, to obtain *from direct experiment* an accurate determination of the place and size of the eyehole, as on this circumstance depends, in a certain degree, the accurate performance of the instrument.

*To centre the two Specula of Gregorian Reflectors.*—Extend two fine threads or wires across the aperture of the tube at right angles, so as to intersect each other exactly in the axis of the telescope. Before the arm is finally fastened to the slider, place it in the tube, and through the eyepiece (without glasses) the intersection of the cross-wires must be seen exactly in the centre of the hole of the arm. When this exactness is obtained, let the arm be firmly riveted and soldered to the slider.

*To centre Lenses.*—The centring of lenses is of great importance, more especially for the object-glasses of achromatic instruments. The following is reckoned a good method: Let the lens to be centred be cemented on a brass chuck, having the middle turned away so as not to touch the lens except near the edge, which will be hid when mounted. This rim is very accurately turned flat where it is to touch the glass. When the chuck and cement is warm, it is made to revolve rapidly; while in motion, a lighted candle is brought before it, and its reflected image attentively watched. If this image has any motion, the lens is not flat or central; a piece of soft wood must therefore be applied to it in the manner of a turning tool, till such time as the light becomes stationary. When the whole has cooled, the edges of the lens must be turned by a diamond, or ground with emery.

For more particular details in reference to grinding and polishing specula and lenses, the reader is referred to Smith's "Complete System of Optics," Imison's "School of Arts," *Huygenii Opera*, Brewster's Appendix to "Ferguson's Lectures," "Irish Transactions," vol. x., or "Nicholson's Journal," vol. xvi. Nos. 65, 66, for January and February, 1807.

# PART III.

## ON VARIOUS ASTRONOMICAL INSTRUMENTS.

### CHAPTER I.

*On Micrometers.*

A MICROMETER is an instrument attached to a telescope, in order to measure small spaces in the heavens, such as the spaces between two stars, and the diameters of the sun, moon, and planets; and by the help of which, the *apparent magnitude* of all objects viewed through telescopes may be measured with great exactness.

There are various descriptions of these instruments, constructed with different substances and in various forms, of which the following constitute the principal variety: the *Wire* Micrometer—the *Spider's-line* Micrometer—the Polymetric Reticle—Divided *Object-glass* Micrometer—Divided *Eyeglass* Micrometer—Ramsden's *Catoptric* Microme-

ter—Rochon's *Crystal* Micrometer—Maskelyne's *Prismatic* Micrometer—Brewster's *Micrometrical Telescope*—Sir W. Herschel's *Lamp* Micrometer—Cavallo's *Mother-of-Pearl* Micrometer, and several others; but, instead of attempting even a general description of these instruments, I shall confine myself merely to a very brief description of *Cavallo's Micrometer*, as its construction will be easily understood by the general reader, as it is one of the most simple of these instruments, and is so cheap as to be procured for a few shillings, while some of the instruments now mentioned are so expensive as to cost nearly as much as a tolerably good telescope.*

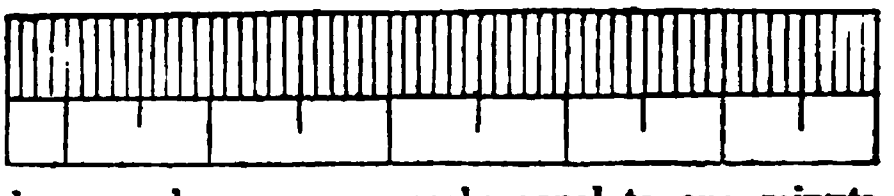
This micrometer consists of a thin and narrow slip of mother-of-pearl finely divided, which is placed in the focus of the eyeglass of a telescope, just where the image of the object is formed; and it may be applied either to a reflecting or a refracting telescope, provided the eyeglass be a convex lens. It is about the twentieth part of an inch broad, and of the thickness of common writing paper, divided into equal parts by parallel lines, every fifth and tenth of which is a little longer than the rest. The simplest way of fixing it is to stick it upon the diaphragm, which generally stands within the tube, and in the focus of the eyeglass. When thus fixed, if you look through the eyeglass, the divisions of the micrometrical scale will appear very distinct, unless the diaphragm is not exactly in the focus of the eyeglass, in which case it must be moved to the proper place; or the micrometer may be placed exactly in the focus of the eyelens by the interposition of a circular piece of paper, card, or by means of wax. If a person should not like to see always the micrometer in the field of the telescope, then the micrometrical scale, instead of being fixed to the diaphragm, may be fitted to a circular perforated plate of brass, of wood, or even of paper, which may be occasionally placed upon the said diaphragm. One of these micrometers, in my possession, which contains 600 divisions in an inch, is fitted up in a separate eyetube, with a glass peculiar to itself, which slides into the eyepiece of the telescope when its own proper glass is taken out.

*To ascertain the Value of the Divisions of this Micrometer.*—Direct the telescope to the sun, and observe how many divisions of the micrometer measure its diameter exactly; then take out of the Nautical Almanac the diameter of the sun for the day on which the observation is made; divide it by the above-mentioned number of divisions, and the quotient is the value of one division of the micrometer. Thus, suppose that 26½ divisions of the micrometer measure the diameter of the sun, and that the Nautical Almanac gives for the measure of the same diameter 31′ 22″, or 1822″: divide 1822 by 26.5, and the quotient is 71″, or 1′ 11″, which is the value of one division of the micrometer, the double of which is the value of two divisions, and so on. The value of the divisions may likewise be ascertained by the passage of an equatorial star over a certain number of divisions in a certain time. The stars best situated for this purpose are such as the following: δ in the Whale, R. A. 37° 3½′, Dec. 37′ 50″ S.; δ in Orion, R. A. 80° 11′ 42″, Dec. 28′ 40″ S.; υ in the Lion, R. A. 171° 25′ 21″, Dec. 23′ 22″ N.; η in Virgo, R. A. 182° 10′, Dec. 33′ 27″ N But the following is the most easy and accurate method of determining the value of the divisions.

Mark upon a wall or other place the length of *six inches*, which may be done by making two dots or lines six inches asunder, or by fixing a six inch ruler upon a stand. Then place the telescope before it, so that the ruler or six-inch length may be at right angles with the direction of the telescope, and just 57 feet 3½ inches distant from the object-glass of the telescope; this done, look through the telescope at the ruler, or other extension of six inches, and observe how many divisions of the micrometer are equal to it, and that same number of divisions is equal to half a degree, or 30′; and this is all that is necessary for the required determination; the reason of which is, because an extension of six inches subtends an angle of 30′ at the distance of 57 feet 3½ inches, as may be easily calculated from the rules of Plane Trigonometry

Fig. 85 exhibits this micrometer scale, but shows it four times larger than the real size of one which was adapted to a three-feet achromatic telescope magnifying 84 times. The divisions upon it are the 200ths of an inch, which reach from one edge of the scale to about the middle of it, excepting every fifth and tenth division, which are longer. Two divisions of this

Fig. 85.



scale are very nearly equal to one minute. and as a quarter of one of these divisions may be distinguished by estimation, therefore an angle of one-eighth of a minute, or of 7½″, may be measured with it. When a telescope magnifies more, the divisions of the microme-

* A particular description of the micrometers here enumerated, and several others, will be found in Dr. Pearson's "Introduction to Practical Astronomy," vol. ii.

ter must be more minute. When the focus of the eyeglass of the telescope is shorter than half an inch, the micrometer may be divided with the 500ths of an inch; by means of which, and the telescope magnifying about 200 times, one may easily and accurately measure an angle smaller than half a second. On the other hand, when the telescope does not magnify above 30 times, the divisions need not be so minute. In one of Dollond's pocket telescopes, which, when drawn out for use, is only 14 inches long, a micrometer with the hundredths of an inch is quite sufficient, and one of its divisions is equal to little less than three minutes, so that an angle of a minute may be measured by it. Supposing 11½ of those divisions equal to 30′, or 23 to a degree, any other angle measured by any other number of divisions is determined by proportion. Thus, suppose the diameter of the sun, seen through the same telescope, be found equal to 12 divisions, say, as 11½ divisions are to 30 minutes, so are 12 divisions to $\left(\frac{12+30}{11.5}\right)$ 31.3, which is the required diameter of the sun.

*Practical Uses of this Micrometer.*—This micrometer may be applied to the following purposes; 1. For measuring the apparent diameters of the sun, moon, and planets. 2. For measuring the apparent distances of the satellites from their primaries. 3. For measuring the cusps of the moon in eclipses. 4. For measuring the apparent distances between two contiguous stars—between a star and a planet—between a star and the moon—or between a comet and the contiguous stars, so as to determine its path. 5. For finding the difference of declination of contiguous stars, when they have nearly the same right ascension. 6. For measuring the small elevations or depressions of objects above and below the horizon. 7. For measuring the proportional parts of buildings, and other objects in perspective drawing. 8. For ascertaining whether a ship at sea, or any moving object, is coming nearer or going further off; for if the angle subtended by the object appears to increase, it shows that the object is coming nearer, and if the angle appears to decrease, it indicates that the object is receding from us. 9. For ascertaining the real distances of objects of known extension, and hence to measure heights, depths, and horizontal distances. 10. For measuring the real extensions of objects when their distances are known. 11. For measuring the distance and size of an object when neither of them is known.

When the micrometer is adapted to those telescopes which have four glasses in the eyetube, *and when the eyetube only is used*, it may be applied to the following purposes: 1. For measuring the real or lineal dimensions of small objects, instead of the angles; for if the tube be unscrewed from the rest of the telescope, and applied to small objects, it will serve for a microscope, having a considerable magnifying power, as we have already shown (p. 124;) and the micrometer, in that case, will measure the lineal dimensions of the object, as the diameter of a hair, the length of a flea, or the limbs of an insect. In order to find the value of the divisions for this purpose, we need only apply a ruler, divided into tenths of an inch, to the end of the tube, and looking through the tube, observe how many divisions of the micrometer measure one-tenth of an inch on the ruler, which will give the required value. Thus, if 30 divisions are equal to $\frac{1}{10}$th of an inch, 300 of them must be equal to the 300th part of an inch. 2. For measuring the magnifying power of other telescopes. This is done by measuring the diameter of the pencil of light at the eye-end of the telescope in question; for, if we divide the diameter of the object-lens by the diameter of this pencil of light, the quotient will express how many times that telescope magnifies in diameter. Thus, suppose that 300 divisions of the micrometer are equal to the apparent extension of one inch—that the pencil of light is measured by four of these divisions—and that the diameter of the object-lens measures one inch and two tenths: Multiply 1.2 by 300, and the product 360, divided by 4, gives 90 for the magnifying power of the telescope.

*Problems which may be solved by this Micrometer.*—1. The angle—not exceeding one degree—which is subtended by an extension of one foot, being given, to find its distance from the place of observation: Rule 1. If the angle be expressed in minutes, say, as the given angle is to 60, so is 687.55 to a fourth proportional, which gives the answer in inches. 2. If the angle be expressed in seconds, say, as the given angle is to 3600, so is 687.55 to a fourth proportional, which expresses the answer in inches. 3. If the angle be expressed in minutes and seconds, turn it all into seconds, proceed as above. Example: At what distance is a globe of one foot in diameter when it subtends an angle of two seconds? 2 : 3600 : : 687.55 : $\frac{3600+687.55}{2}$ —1237596 inches, or 103132½ feet—the answer required. II. The angle which is subtended by any known extension being given, to find its distance from the place of observation: Rule: Proceed as if the extension were of one foot, by Problem I., and call the answer B; then, if the extension in question be expressed in inches, say as 12 inches are to that extension, so is B to a fourth proportional,

which is the answer in inches. But if the extension in question be expressed in feet, then we need only multiply it by B, and the product is the answer in inches. Example: At what distance is a man six feet high when he appears to subtend an angle of 30″? By Problem I., if the man were one foot high the distance would be 82506 inches; but as he is six feet high therefore multiply 82506 by 6, and the product is the required distance, namely, 495036 inches, or 41253 feet.

For greater convenience, especially in travelling, when one has not the opportunity of making such calculations, the following two tables have been calculated, the first of which shows the distance answering to any angle from one minute to one degree, which is subtended by a man whose height is considered an extension of six feet, because at a mean, such is the height of a man when dressed with hat and shoes on. These tables may be transcribed on a card, and may be kept always ready with a pocket telescope furnished with a micrometer. Their use is to ascertain distances without any calculations; and they are calculated only to minutes, because with a pocket telescope and micrometer it is not possible to measure an angle more accurately than to a minute. Thus, if we want to measure the extension of a street, let a foot ruler be placed at the end of the street; measure the angular appearance of it, which suppose to be 36′, and in the table we have the required distance against 36′, which is 95½ feet. Thus, also, a man who appears to be 49′ high is at the distance of 421 feet. Again: Suppose the trunk of a tree, which is known to be three feet in diameter, be observed to subtend an angle of 9½′. Take the number answering to 9′ out of the table, namely, 382, and subtract from it a proportional part for the half minute, namely, 19.1, which, subtracted from 382, leaves 362.9. This multiplied by 3, the diameter of the tree, produces 1087, 7 feet — the distance from the object end of the telescope.

| Angles subtended by an extension of *one foot* at different distances. | | | |
|---|---|---|---|
| Angles in minutes. | Distances in feet. | Angles in minutes. | Distances in feet. |
| 1 | 3438 | 31 | 110.9 |
| 2 | 1719 | 32 | 107.4 |
| 3 | 1146 | 33 | 104.2 |
| 4 | 859.4 | 34 | 101.1 |
| 5 | 687.5 | 35 | 98.2 |
| 6 | 572.9 | 36 | 95.5 |
| 7 | 491.1 | 37 | 92.9 |
| 8 | 429.7 | 38 | 90.4 |
| 9 | 382 | 39 | 88.1 |
| 10 | 343.7 | 40 | 85.9 |
| 11 | 312.5 | 41 | 83.8 |
| 12 | 286.5 | 42 | 81.8 |
| 13 | 264.4 | 43 | 79.9 |
| 14 | 245.5 | 44 | 78.1 |
| 15 | 229.2 | 45 | 76.4 |
| 16 | 214.8 | 46 | 74.7 |
| 17 | 202.2 | 47 | 73.1 |
| 18 | 191 | 48 | 71.6 |
| 19 | 181 | 49 | 70.1 |
| 20 | 171.8 | 50 | 68.7 |
| 21 | 162.7 | 51 | 67.4 |
| 22 | 156.2 | 52 | 66.1 |
| 23 | 149.4 | 53 | 64.8 |
| 24 | 143.2 | 54 | 63.6 |
| 25 | 137.5 | 55 | 62.5 |
| 26 | 132.2 | 56 | 61.4 |
| 27 | 127.3 | 57 | 60.3 |
| 28 | 122.7 | 58 | 59.1 |
| 29 | 118.5 | 59 | 58.2 |
| 30 | 114.6 | 60 | 57.3 |

| Angles subtended by an extension of *six feet* at different distances. | | | |
|---|---|---|---|
| Angles in minutes. | Distances in feet. | Angles in minutes. | Distances in feet. |
| 1 | 20626.8 | 31 | 665.4 |
| 2 | 10313 | 32 | 644.5 |
| 3 | 6875.4 | 33 | 625 |
| 4 | 5156.5 | 34 | 606.6 |
| 5 | 4125.2 | 35 | 589.3 |
| 6 | 3437.7 | 36 | 572.9 |
| 7 | 2946.6 | 37 | 557.5 |
| 8 | 2578.2 | 38 | 542.8 |
| 9 | 2291.8 | 39 | 528.9 |
| 10 | 2062.6 | 40 | 515.6 |
| 11 | 1875.2 | 41 | 503.1 |
| 12 | 1718.8 | 42 | 491.1 |
| 13 | 1586.7 | 43 | 479.7 |
| 14 | 1473.3 | 44 | 468.8 |
| 15 | 1375 | 45 | 458.4 |
| 16 | 1298.1 | 46 | 448.4 |
| 17 | 1213.3 | 47 | 438.9 |
| 18 | 1145.9 | 48 | 429.7 |
| 19 | 1085.6 | 49 | 421 |
| 20 | 1031.4 | 50 | 412.5 |
| 21 | 982.2 | 51 | 404.4 |
| 22 | 937.6 | 52 | 396.7 |
| 23 | 896.8 | 53 | 389.2 |
| 24 | 859.4 | 54 | 381.9 |
| 25 | 825 | 55 | 375 |
| 26 | 793.3 | 56 | 368.3 |
| 27 | 763.9 | 57 | 361.9 |
| 28 | 736.6 | 58 | 355.6 |
| 29 | 711.3 | 59 | 349.6 |
| 30 | 687.5 | 60 | 343.7 |

In this way the distance of a considerably remote object, as a town or building at ten or twelve miles' distance, may be very nearly determined, provided we have the lineal dimensions of a house or other object that stands at right angles to the line of vision. The breadth of a river, of an arm of the sea, or the distance of a lighthouse, whose elevation above the sea or any other point is known, may likewise, in this manner be easily determined.

## CHAPTER II.

### *On the Equatorial Telescope, or Portable Observatory.*

The equatorial instrument is intended to answer a number of useful purposes in Practical Astronomy, independently of any particular observatory. Besides answering the general purpose of a quadrant, a transit instrument, a theodolite, and an azimuth instrument, it is almost the only instrument adapted for viewing the stars and planets *in the day-time*, and for following them in their apparent diurnal motions. It may be made use of in any steady room or place, and performs most of the useful problems in astronomical science.

The basis of all equatorial instruments is a revolving axis, placed parallel to the axis of the earth, by which an attached telescope is made to follow a star or other celestial body in the arc of its diurnal revolution, without the trouble of repeated adjustments for changes of elevation, which quadrants and circles with vertical and horizontal axes require. Such an instrument is not only convenient for many useful and interesting purposes in celestial observations, but is essentially requisite in certain cases, particularly in examining and measuring the relative positions of two contiguous bodies, or in determining the diameters of the planets, when the spider's-line micrometer is used.

Christopher Scheiner is supposed to have been the first astronomer who, in the year 1620, made use of a polar axis, but without any appendage of graduated circles. It was not, however, till the middle of the last century that any instruments of this description, worthy of the name, were attempted to be constructed. In 1741, Mr. Henry Hindley, a clockmaker in York, added to the polar axis an equatorial plate, a quadrant of altitude, and declination semicircle; but when this piece of mechanism was sent to London for sale in 1748, it remained unsold for the space of 13 years. Mr. Short, the optician, published in the Philosophical Transactions for 1750 a "description of an equatorial telescope," which was of the reflecting kind, and was mounted over a combination of circles and semicircles, which were strong enough to support a tube, and a speculum of the Gregorian construction 18 inches in focal length. This instrument consisted of a somewhat cumbersome and expensive piece of machinery, a representation of which may be seen in vol. iii. of Martin's "*Philosophia Britannica*, or System of the Newtonian Philosophy." Various modifications of this instrument have since been made by Nairne, Dollond, Ramsden, Troughton, and other artists; but even at the present period it has never come into very general use, though it is one of the most pleasant and useful instruments connected with astronomical observations.

As many of these instruments are somewhat complicated and very expensive, I shall direct the attention of the reader solely to one which I consider as the most simple, which may be purchased at a moderate expense, and is sufficiently accurate for *general* observations.

The instrument consists of the following parts: A *horizontal circle, E F* (fig. 86,)

Fig. 86.

divided into four quadrants of 90 degrees each. There is a fixed nonius at *N*; and the circle is capaple of being turned round on an axis. In the centre of the horizontal circle is fixed a

strong upright pillar, which supports the centre of a vertical semi-circle, *A B*, divided into two quadrants of 90 degrees each. This is called the *semicircle of altitude*, and may, at any time, serve the purpose of a quadrant in measuring either altitudes or depressions. It has a nonius plate at *K*. At right angles to the plane of this semicircle, the *equatorial circle*, *M N*, is firmly fixed. It represents the equator, and is divided into twice twelve hours, every hour being divided into twelve parts of five minutes each. Upon the equatorial circle moves another circle, with a chamfered edge, carrying a nonius, by which the divisions on the equatorial may be read off to single minutes; and at right angles to this movable circle is fixed the *semicircle of declination*, *D*, divided into two quadrants of 90 degrees each. The telescope, *P O*, is surmounted above this circle, and is fixed to an index movable on the semicircle of declination, and carries a nonius opposite to *Q*. The telescope is furnished with two or three Huygenian eyepieces and likewise with a diagonal eyepiece for viewing objects near the zenith. Lastly, there are two spirit levels fixed on the horizontal circle at right angles to each other, by means of which this circle is made perfectly level when observations are to be made.

*To adjust the Equatorial for Observations.*—Set the instrument on a firm support; then, *to adjust the levels and the horizontal circle*, turn the horizontal circle till the beginning *O* of the divisions coincides with the middle stroke of the nonius, or near it. In this situation, one of the levels will be found to lie either in a right line joining the two foot-screws which are nearest the nonius, or else parallel to such a right line. By means of the last two screws, cause the bubble in the level to become stationary in the middle of the glass; then turn the horizontal circle half round by bringing the other *O* to the nonius; and if the bubble remains in the middle as before, the level is well adjusted; if it does not, correct the position of the level by turning one or both of the screws which pass through its ends till the bubble has moved half the distance it ought to come to reach the middle, and cause it to move the other half by turning the foot-screws already mentioned; return the horizontal circle to its first position, and if the adjustments have been well made, the bubble will remain in the middle; if otherwise, the process must be repeated till it bears this proof of its accuracy; then turn the horizontal circle till 90° stands opposite to the nonius; and by the foot-screw immediately opposite the other 90°, cause the bubble of the same level to stand in the middle of the glass; lastly, by its own proper screws set the other level so that its bubble may occupy the middle of its glass.

*To adjust the Line of Sight.*—Set the nonius on the *declination* semicircle at *O*, the nonius on the horary circle at VI., and the nonius on the semicircle of altitude at 90; look through the telescope towards some part of the horizon where there is a diversity of remote objects; level the horizontal circle, and then observe what object appears in the centre of the cross-wires, or in the centre of the field of view if there be no wires: reverse the semicircle of altitude so that the other 90° may apply to the nonius, taking care, at the same time, that the other three noniuses continue at the same parts of their respective graduations as before. If the remote object continues to be seen on the centre of the cross-wires, the line of sight is truly adjusted.

*To find the Correction to be applied to Observations by the Semicircle of Altitude.*—Set the nonius on the declination semicircle to 0, and the nonius on the horary circle to XII.; direct the telescope to any fixed and distant object by moving the horizontal circle and semicircle of altitude, and nothing else; note the degree and minute of altitude or depression; reverse the declination semicircle by directing the nonius on the horary circle to the opposite XII.; direct the telescope again to the same object, by means of the horizontal circle and semicircle of altitude, as before. If its altitude or depression be the same as was observed in the other position, no correction will be required; but if otherwise, half the difference of the two angles is the correction to be added to all observations made with that quadrant, or half of the semicircle which shows the least angle, or to be subtracted from all the observations made with the other quadrant, or half of the semicircle. When the levels and other adjustments are once truly made, they will be preserved in order for a length of time, if not deranged by violence; and the correction to be applied to the semicircle of altitude is a constant quantity.

*Description of the Nonius.*—The nonius—sometimes called the *Vernier*—is a name given to a device for subdividing the arcs of quadrants and other astronomical instruments. It depends on the simple circumstance that if any line be divided into equal parts, the length of each part will be greater the fewer the divisions; and contrariwise, it will be less in proportion as those divisions are more numerous. Thus, in the equatorial now described, the distance between the two extreme strokes on the nonius is exactly equal to eleven degrees on the limb, only that it is divided into twelve equal parts. Each of these last parts will therefore be shorter than the *degree* on the limb in the proportion of 11 to 12, that is to

say, it will be $\frac{1}{12}$th part, or five minutes shorter; consequently, if the middle stroke be set precisely opposite to any degree, the relative positions of the nonius and the limb must be altered five minutes of a degree before either of the two adjacent strokes next the middle on the nonius can be brought to coincide with the nearest stroke of a degree; and so likewise the second stroke on the nonius will require a change of ten minutes, the third of fifteen, and so on to thirty, when the middle line of the nonius will be seen to be equidistant between two of the strokes on the limb; after which, the lines on the opposite side of the nonius will coincide in succession with the strokes on the limb. It is clear from this that whenever the middle stroke of the nonius does not stand precisely opposite to any degree, the odd minutes, or distance between it and the degree immediately preceding, may be known by the *number* of the stroke marked on the nonius, which coincides with any of the strokes on the limb.* In some instruments the nonius-plate has its divisions fewer than the number of parts on the limb to which it is equal; but when once a clear idea of the principle of any nonius is obtained, it will be easy to transfer it to any other mode in which this instrument is contrived.

*To find by this Equatorial the* MERIDIAN LINE, and the Time, FROM ONE OBSERVATION OF THE SUN.—In order to this, it is requisite that the sun's declination and the latitude of the place be known. The declination of the sun may be found for every day in the Nautical Almanac, or any other astronomical ephemeris; and the latitude of the place may be found by means of the semicircle of altitude, when the telescope is directed to the sun or a known fixed star. It is likewise requisite to make the observation when the azimuth and altitude of the sun alter quickly, and this is generally the case the further that luminary is from the meridian; therefore, at the distance of three or four hours either before or after noon, (in summer,) adjust the horizontal circle; set the semicircle of altitude so that its nonius may stand at the colatitude of the place; lay the plane of the last-mentioned semicircle in the meridian by estimation, its 0 being directed towards the depressed pole; place the nonius of the declination semicircle to the declination, whether north or south; then direct the telescope towards the sun, partly by moving the declination semicircle on the axis of the equatorial circle, and partly by moving the horizontal circle on its own axis. There is but one position of these which will admit of the sun being seen exactly in the middle of the field of view. When this position is obtained, the nonius on the equatorial circle shows *the apparent time, and the circle of altitude is in the plane of the meridian.* When this position is ascertained, the meridian may be settled by a landmark at a distance.

With an equatorial instrument nearly similar to that now described, I formerly made a series of "*day observations* on the celestial bodies," which were originally published in vol. xxxvi. of "Nicholson's Journal of Natural Philosophy," and which occupy twenty pages of that journal. Some of these observations I shall lay before the reader, after having explained the manner in which they are made.

The instrument was made by Messrs. W. and S. Jones, opticians, Holborn, London. The telescope which originally accompanied the instrument was an achromatic refractor, its object-glass being 8½ inches focal distance, and one inch in diameter. This telescope, not admitting sufficiently high magnifying powers for the observations intended, was afterwards thrown aside for another telescope having an object-glass 20 inches focal length and 1¾th inches in diameter, which was attached to the equatorial machinery in place of the small telescope. It was furnished with magnifying powers of 15, 30, 45, 60, and 100 times. The instrument was placed on a firm pedestal about three feet high. The feet of this pedestal had short iron pikes, which slipped into corresponding holes in the floor of the apartment adjacent to a south window, so that when the direction of the meridian was found, and the circles properly adjusted, the instrument was in no danger of being shifted from this position. Though this instrument generally stood fronting the southern part of the heavens, yet the equatorial part, along with the telescope, could occasionally be removed to another position fronting the north and north-west, for observing the stars in those quarters.

*Manner of observing Stars and Planets in the Daytime by the Equatorial.*—Before such observations can be made, the semicircle of altitude must be placed in the meridian, and the degree and minute pointed out by the nonius on the horizontal circle, when in this position, noted down in a book, so that it may be placed again in the same position, should any derangement afterward happen. The semicircle of altitude must be set to the colatitude of the place, that is, to what the latitude wants of 90°. Suppose the latitude of the place of observation be 52° 30′ north, this latitude subtracted from 90° leaves 37° 30′ for the colatitude, and therefore the semicircle of altitude, on which the equatorial circle is fixed, must be elevated to 37° 30′, and

* Adams's Introduction to Practical Astronomy.

then the equatorial circle on the instrument coincides with the equator in the heavens. Lastly, the telescope must be adjusted on the declination semicircle so as exactly to correspond with the declination of the heavenly body to be viewed. If the body is in the equator, the telescope is set by the index at 0 on the semicircle of declination, or at the middle point between the two quadrants, and then, when the telescope, along with the semicircle of declination, is moved from right to left, or the contrary, it describes an arc of the equator. If the declination of the body be north, the telescope is elevated to the northern division of the semicircle; if south, to the southern part of it.

These adjustments being made, take the difference between the right ascension of the sun and the body to be observed, and if the right ascension of the body be greater than that of the sun, subtract the difference from the time of observation; if not, add to the time of observation.* The remainder in one case, or the sum in the other, will be the hour and minute to which the nonius on the equatorial circle is to be set; which being done, the telescope will point to the star or planet to whose declination the instrument is adjusted. When the heavenly body is thus found, it may be followed, in its diurnal course, for hours, or as long as it remains above the horizon; for as the diurnal motion of a star is parallel to the equator, the motion of the telescope on the equatorial circle will always be in the star's diurnal arc; and should it have left the field of the telescope for any considerable time, it may be again recovered by moving the telescope onward according to the time which elapsed since it was visible in the field of view. We may illustrate what has been now stated by an example or two: Suppose, on the 30th of April, 1841, at 1 o'clock P.M., we wished to see the star *Aldebaran*: the right ascension of this star is $4^h\ 27^m$, and the sun's right ascension for that day at noon, as found in "White's Ephemeris" or the "Nautical Almanac," is $2^h\ 30^m$; subtract this last number from $4^h\ 27^m$, and the remainder $1^h\ 57^m$, shows that the star comes to the meridian on that day at 57 minutes past 1 o'clock P.M.; and as the time of observation is 1 P.M., the nonius which moves on the equatorial circle must be set to three minutes past XI. as the star is at that hour 57 minutes from the meridian. The declination of Aldebaran is 16° 11′ north, to which point on the semicircle of declination the telescope must be adjusted, and then the star will be visible in the field of view. Again: suppose we wished to observe the planet Venus on the 1st of January, 1842, at 12 o'clock noon: the sun's right ascension on that day is $18^h\ 46^m$, and that of Venus $17^h\ 41^m$, from which the sun's right ascension being subtracted, the remainder is $22^h\ 55^m$, or 55 minutes past 10 A.M. Here, as the right ascension of Venus is too small to have the sun's right ascension taken from it, we borrow 24 hours, and reckon the remainder from XII. at noon. As the planet at 12 noon is one hour and five minutes past the meridian, the nonius on the equatorial circle must be set to that point, and the telescope adjusted to 23° 6′ of south declination, which is the declination of Venus for that day, when this planet will appear in the field of view.

* Or find the sun's right ascension for the given day; subtract this from the star or planet's right ascension, and the remainder is the approximate time of the star's coming to the meridian. The difference between this time and the time of observation will then determine the point to which the telescope is to be directed.

### *Observation on the Fixed Stars and Planets, made in the Daytime by the Equatorial.*

For the purpose of illustrating the descriptions now given, and for affording some information respecting celestial day observations, I shall select a few of the observations above alluded to, which I formerly published in Nicholson's Journal, along with a few others which have been since made. These observations were made with a view to determine the following particulars: 1. What stars and planets may be conveniently seen in the daytime when the sun is above the horizon? 2. What degrees of magnifying power are requisite for distinguishing them? 3. How near their conjunction with the sun they may be seen? and, 4. Whether the diminution of the aperture of the object-glass of the telescope, or the increase of magnifying power, conduces most to render a star or a planet visible in daylight. Having never seen such observations recorded in books of astronomy or in scientific journals, I was induced to continue them, almost every clear day, for nearly a year, in order to determine the points now specified. Some of the results are stated in the following pages.

*Observations on Fixed Stars of the first Magnitude.*—April 23, 1813, at $10^h\ 16^m$ A.M., the sun being $5\frac{1}{2}$ hours above the horizon, saw tho star *Vega*, or $\alpha$ Lyræ, very distinctly with a power of 30 times. Having contracted the aperture of the object-glass to $\frac{9}{10}$ths of an inch, saw it on a darker ground, but not more plainly than before. Having contracted the aperture still further to half an inch, I perceived the star, but not so distinctly as before. The sky being very clear, and the star in a a quarter of the heavens nearly opposite to the sun, I diminished the magnifying power to 15, and could still perceive the star, but indistinctly; it was just perceptible. August

23, at $0^h$ $12^m$ P.M., saw the star *Capella* or α *Aurigæ*, with a power of 60, and immediately afterward with a power of 30, the aperture undiminished. With this last power it appeared extremely distinct, but not so brilliant and splendid as with the former power. Having diminished the aperture to $\frac{9}{10}$ths of an inch, it appeared on a darker ground, though in the former case it was equally perceptible. A few minutes afterward, could distinguish it with a power of 15, the aperture being contracted to half an inch. It appeared very small; it was with difficulty the eye could fix upon it in the field of the telescope; but when it was once perceived, its motion across the field of view could be readily followed. It could not be perceived when the diminished aperture was removed. The sun was then shining in meridian splendour.

August 10th, $9^h$ $30^m$ A.M., saw the star Sirius with a power of 60, the aperture contracted to $\frac{9}{10}$ths of an inch; saw it likewise when the aperture was diminished to half an inch, but not so distinctly as through the aperture of $\frac{9}{10}$ths of an inch. Having put on a power of 30, could distinguish it distinctly enough through each of the former apertures, and likewise when they were removed, but somewhat more distinctly with the apertures of nine-tenths and an half inch than without them. At this time the star was $2^h$ $42^m$ in time of right ascension west of the sun, having an elevation above the horizon of about 17° 10′, the sun shining bright, and the sky very much enlightened in that quarter of the heavens where the star appeared. There was also a considerable undulation of the air, which is generally the case in the hot mornings of summer, which renders a star more difficult to be perceived than in the afternoon, especially when it is viewed at a low altitude. June 4th, $1^h$ $30^m$ P.M., saw Sirius with a power of 30 with great distinctness, the aperture not contracted. The star was then within $1^h$ $50^m$ in time of right ascension east from the sun. August 24th, $9^h$ $5^m$ A.M., saw the star *Procyon*, α *Canis Minoris*, distinctly with a power of 60, the aperture not contracted. When diminished to $\frac{9}{10}$ths of an inch, it appeared rather more distinct, as the ground on which it was seen was darker. With a power of 30, and the aperture contracted to $\frac{9}{10}$ths of an inch, could perceive it, but somewhat indistinctly. When the equatorial motion was performed in order to keep it in the field of view, it was some time before the eye could again fix upon it. When the aperture was diminished to half an inch, it could not be perceived. Saw it when both the apertures were removed, but rather more distinctly with the aperture of $\frac{9}{10}$ths of an inch. The difference in the result of this observation from that of Capella above stated was owing to the star's proximity to the sun, and the consequent illumination of the sky in that quarter where it appeared. Its difference in right ascension from that of the sun was then about $2^h$ $5^m$ of time, and its difference of declination about 4° 50′.* This star may be considered as one of those which rank between the first and second magnitudes.

Similar observations to the above were made and frequently repeated on the stars Rigel, Aldebaran, Betelguese, Cor Leonis, and other stars of the first magnitude, which gave nearly the same results. The stars Altares and Fomalhaut are not so easily distinguished, on account of their great southern declination, and consequent low elevation above the horizon. The following observation on *Arcturus* may be added. June 3d, observed Arcturus very distinctly a little before seven in the evening,—the sun being about $1^h$ $40^m$ above the horizon, and shining bright—with a power of 15, the aperture not contracted. It appeared very small, but distinct. This star is easily distinguishable at any time of the day with a power of 30.

*Observations on Stars of the Second Magnitude.*—May 5, 1813, at $6^h$ P.M., the sun being an hour and three-quarters above the horizon, saw *Alphard*, or α Hydræ, a star of the second magnitude, with a power of 60, the aperture diminished to $\frac{9}{10}$ths of an inch. A few minutes afterward could perceive it, but indistinctly, with a power of 30, the aperture contracted as above. It could not be seen very distinctly with this power till about half an hour before sunset. It was then seen rather more distinctly when the aperture was contracted than without the contraction. May 7th, saw the star *Deneb*, or β *Leonis*, distinctly with a power of 60, about an hour and a half before sunset. August 20th, saw Ras Alhague, or α *Ophiuchi*, at $4^h$ $40^m$ P.M., with a power of 100, the sun being nearly three hours above the horizon, and shining bright. Perceived it about an hour afterward with a power of 60, with the aperture contracted to $\frac{9}{10}$ths of an inch, and also when this contraction was removed. The star was seen nearly as distinctly in the last case as in the first. August 27, $5^h$ P.M., the same star appeared

* The right ascensions, declinations, longitudes, &c., stated in these memoranda, which were noted at the time of observation, are only approximations to the truth, perfect accuracy in these respects being of no importance in such observations. They are, however, in general, within a minute or two of the truth. The *times* of the observations, too, are noted in reference, not to the *astronomical*, but to the *civil* day. The astronomical day commences at 12 noon, and the hours are reckoned, without interruption, to the following noon. The civil day commences at 12 midnight.

quite distinct with a power of 60, the aperture not contracted. It did not appear more distinct when the aperture was contracted to $\frac{8}{10}$ths of an inch. The sun was then more than two hours above the horizon. August 28th, saw the star *Pollux* or, β *Gemini*, two hours after sunrise, with a power of 60, aperture undiminished. November 12th, 1h 30′ P.M., saw the star *Altair*, or α *Aquilæ*, with an 8½ inch telescope, one inch aperture, carrying a power of 45, the aperture not contracted. Having contracted the aperture a little, it appeared somewhat less distinct. This star is reckoned by some to belong to the class of stars of the first magnitude, but in White's "Ephemeris" and other Almanacs it is generally marked as being of the second magnitude. It forms a kind of medium between stars of of the first and second magnitude.

Similar observations, giving the same results, were made on the stars Bellatrix, Orion's Girdle, α Andromedæ, α Pegasi, Alioth, Benetnach, North Crown, or α Coronæ Borealis, and various other stars of the same magnitude.

From the above and several hundreds of similar observations, *the following conclusions* are deduced:

1. That a magnifying power of 30 times is sufficient for distinguishing a fixed star of the first magnitude, even at noonday, at any season of the year, provided it have a moderate degree of elevation above the horizon, and be not within 30° or 40° of the sun's body; also, that by a magnifying power of 15, a star of this class may be distinguished when the sun is not more than an hour and a half above the horizon; but, in every case, higher powers are to be preferred. Powers of 45 or 60, particularly the last, were found to answer best in most cases, as with such powers the eye could fix on the star with ease as soon as it entered the field of the telescope.

2. That most of the stars of the second magnitude may be seen with a power of 60 when the sun is not much more than two hours above the horizon; and, at any time of the day, the brightest stars of this class may be seen with a power of 100 when the sky is serene, and the star not too near the quarter in which the sun appears.

3. That, in every instance, an increase of magnifying power has the principal effect in rendering a star easily perceptible; that diminution of aperture, in most cases, produces a very slight effect—in some cases, none at all; and, when the aperture is contracted beyond a certain limit, it produces a hurtful effect. The cases in which a moderate contraction is useful are the two following: 1. When the star appears in a bright part of the sky, not far from that quarter in which the sun appears. 2. When an object-glass of a large aperture and a small degree of magnifying power is used. In almost every instance, the contraction of the object-glass of the 8½ inch telescope with a power of 45 had a hurtful effect; but when the 20 inch telescope carried a power of only 15, the contraction served to render the object more perceptible.

### *Observations on the Planets made in the Daytime.*

Some of the planets are not so easily distinguished in the daytime as the fixed stars of the first magnitude. The one which is most easily distinguished at all times is the planet Venus.

1. *Observations on Venus.*—My observations on this planet commenced about the end of August, 1812, about three or four weeks after its inferior conjunction. About that period, between ten and eleven in the forenoon, with a power of 45, it appeared as a beautiful crescent, quite distinct and well defined, with a lustre similar to that of the moon about sunset, but of a whiter colour. The view of its surface and phase was fully more distinct and satisfactory than what is obtained in the evening after sunset; for, being at a high elevation, the undulation near the horizon did not affect the distinctness of vision. The planet was then very distinctly seen with a power of seven times, when it appeared like a star of the first or second magnitude. I traced the variation of its phases almost every clear day till the month of May, 1813. As at that time it was not far from its superior conjunction with the sun, I wished to ascertain how near its conjunction with that luminary it might be seen, and particularly whether it might not be possible, in certain cases, to see it at the moment of its conjunction.

The expressions of all astronomical writers previous to this period, when describing the phases of Venus, either directly assert, or at least imply, that it is *impossible* to see that planet, in any instance, at the time of its superior conjunction. This is the language of Dr. Long, Dr. Gregory, Dr. Brewster, Ferguson, Adams, B. Martin, and most other writers on the science of Astronomy. How far such language is correct will appear from the following observations and remarks.

April 24, 1813, 10h 50′ A.M., observed Venus with a power of 30, the aperture not contracted. She was then about 31 minutes of time in right ascension distant from the sun, their difference of declination 3° 59′. She appeared distinct and well defined. With a power of 100, could distinguish her gibbous phase. May 1st, 10h 20m A.M., viewed this planet with a power of 60, the aperture not contracted. It appeared distinct. Saw it about the same time with a power of 15, the aperture

being contracted to $\frac{2}{10}$ths of an inch. Having contracted the aperture to half an inch, saw it more distinctly. When the contracted apertures were removed, the planet could with difficulty be distinguished, on account of the direct rays of the sun striking on the inside of the tube of the telescope. The sun was shining bright, and the planet about 25′ of time in R. A. west of his centre, their difference of declination being 3° 7′. May 7th, $10^h$ A.M., saw Venus distinctly with a power of 60, the sun shining bright. It was then about 19′ of time in R A., and 4° 27′ in longitude west of the sun, their difference of declination being 2° 18′. I found a diminution of aperture particularly useful when viewing the planet at this time, even when the higher powers were applied. This was the last observation I had an opportunity of making prior to the conjunction of Venus with the sun, which happened on May 25th, at $9^h$ $3^m$ A.M. Its geocentric latitude at that time being about 16′ south, the planet must have passed almost close by the sun's southern limb. Cloudy weather for nearly a month after the last observation prevented any further views of the planet, when it was in that part of the heavens which was within the range of the instrument. The first day that proved favourable after it had passed the superior conjunction was June 5th. The following is the memorandum of the observation then taken:

June 5th, $9^h$ A.M., adjusted the equatorial telescope for viewing the planet Venus, but it could not be perceived on account of the direct rays of the sun entering the tube of the telescope. I contrived an apparatus for screening his rays, but could not get it conveniently to move along with the telescope, and therefore determined to wait till past eleven, when the top of the window of the place of observation would intercept the solar rays. At $11^h$ $20^m$ A.M., just as the sun had passed the line of sight from the eye to the top of the window, and his body was eclipsed by it, I was gratified with a tolerably distinct view of the planet, with a power of 60, the aperture being contracted to $\frac{2}{10}$ths of an inch. This distinctness increased as the sun retired, till, in two or three minutes, the planet appeared perfectly well defined. Saw it immediately afterward with a power of 30, the aperture contracted as before. Saw it also quite distinctly with a power of 15; but it could not be distinguished with this power when the contracted aperture was removed. At this time Venus was just 3° in longitude, or about 13′ in time of R. A. east of the sun's centre, and of course only about $2\frac{3}{4}$th degrees from his eastern limb; the difference of their declination being 27′, and the planet's latitude 11′ north.

Several years afterward I obtained views of this planet when considerably nearer the sun's margin than as stated in the above observation, particularly on the 16th of October, 1819, at which time Venus was seen when only six days and nineteen hours past the time of the superior conjunction. At that time its distance from the sun's eastern limb was only 1° 28′ 42″. A subsequent observation proved that Venus can be seen when only 1° 27′ from the sun's margin, which I consider as approximating to the nearest distance from the sun at which this planet is distinctly visible. I shall only state further the two or three following observations.

June 7th, 1813, $10^h$ A.M., saw Venus with a power of 60, the aperture being contracted to $\frac{2}{10}$ths of an inch, the direct rays of the sun *not being intercepted by the top of the window*. The aperture having been further contracted to half an inch, could perceive her, but not quite so distinctly. When the contractions were removed, she could scarcely be seen. She was then 3° 33′ in longitude, and nearly 15 minutes in time of R. A. distant from the sun's centre. Some fleeces of clouds having moved across the field of view, she was seen remarkably distinct in the interstices, the sun at the same time being partly obscured by them. August 19th, $1^h$ $10^m$ P.M., viewed Venus with a magnifying power of 100. Could perceive her surface and gibbous phase almost as distinctly as when the sun is below the horizon. She appeared bright, steady in her light, and well defined, without that glare and tremulous appearance she exhibits in the evening when near the horizon. She was then nearly on the meridian. On the whole, such a view of this planet is as satisfactory, if not preferable, to those views we obtain with an ordinary telescope in the evening, when it is visible to the naked eye.

All the particulars above stated have been confirmed by many subsequent observations continued throughout a series of years. I shall state only two recent observations, which show that Venus may be seen somewhat nearer the sun than what is deduced from the preceding observations, and at the point of its superior conjunction. March 10th, 1842, observed the planet Venus, then very near the sun, at 19 minutes past 11 A.M. It had passed the point of its superior conjunction with the sun on the 5th of March, at $1^h$ $19^m$ P.M. The difference of right ascension between the sun and the planet was then about $6\frac{1}{2}$ minutes of time, or about 1° $37\frac{1}{2}$′, and it was only about 1° 21′ distant from the sun's eastern limb. It appeared quite distinct and well defined, and might perhaps have been seen on the preceding day, had the observation been then made. The following observation shows that Venus may be seen still

nearer the sun than in the preceding observations, and even *at the moment of its superior* conjunction. On the 2d of October, 1843, this planet passed the point of its superior conjunction with the sun at $4^h$ $15^m$ P.M. At two o'clock P.M., only two hours before the conjunction, I perceived the planet distinctly, and kept it in view for nearly ten minutes, till some dense clouds intercepted the view. It appeared tolerably distinct and well defined, though not brilliant, and with a round, full face, and its apparent path was distinctly traced several times across the field of view of the telescope. I perceived it afterward, about half past four P.M., only a few minutes after it had passed the point of conjunction, on which occasion it appeared less distinct than in the preceding observation, owing to the low altitude of the planet, being then only a few degrees above the horizon. The observations, in this instance, were made, not with an equatorial instrument, which I generally use in such observations, but with a good achromatic telescope of 44½ inches focal distance, mounted on a common tripod, with a terrestrial power of 95 times. A conical tube about ten inches long was fixed on the object-end of the telescope, at the extremity of which an aperture 1½ inches in diameter was placed, so as to intercept, as much as possible, the direct ingress of the solar rays. The top of the upper sash of the window of the place of observation was likewise so adjusted as to intercept the greater part of the sun's rays from entering the tube of the telescope. The sun's declination at that time was 3° 26′ south, and that of Venus 2° 12′ south; consequently, the difference of declination was 1° 14′ = the distance of Venus from the sun's centre; and as the sun's diameter was about 16′, Venus was then only 58′ from the sun's northern limb, or 6′ less than two diameters of the sun.

This is the nearest approximation to the sun at which I have ever beheld this planet, and it demonstrates that Venus may be seen even within a degree of the sun's margin; and it is, perhaps, the nearest position to that luminary in which this planet can be distinctly perceived. It shows that the light reflected from the surface of Venus is far more brilliant than that reflected from the surface of our moon; for no trace of this nocturnal luminary can be perceived, even when at a much greater distance from the sun, nor is there any other celestial body that can be seen within the limit now stated. This is the first observation, so far as my information extends, of Venus having been seen at the time of her superior conjunction.*

The practical conclusion from this observation is, that at the superior conjunction of this planet, when its distance from the sun's margin is not less than 58′, *its polar and equatorial diameter may be measured* by a micrometer, when it will be determined whether or not Venus be of a *spheroidal* figure. The Earth, Mars, Jupiter, and Saturn are found to be, not spheres, but *spheroids*, having their polar shorter than their equatorial diameters. But the true figure of Venus has never yet been ascertained, because it is only at the superior conjunction that she presents a full, enlightened hemisphere, and when both diameters can be measured, except at the time when she transits the sun's disk, which happens only twice in the course of 120 years.†

* This observation is inserted in the "Edinburgh Philosophical Journal" for January, 1844.

† The late Dr. Benjamin Martin, when describing the nature of the solar telescope, in his "*Philosophia Britannica*," vol. iii. p. 85, gives the following relation: "I cannot here omit to mention a very *unusual phenomenon* that I observed about ten years ago in my darkened room. The window looked towards the west, and the spire of Chichester Cathedral was before it at the distance of 50 or 60 yards. I used very often to divert myself by observing the pleasant manner in which the sun passed behind the spire, and was eclipsed by it for some time; for the image of the sun and of the spire were very large, being made by a lens of 12 feet focal distance; and once, as I observed the occultation of the sun behind the spire, just as the disk disappeared, I saw several small, bright, round bodies or balls running towards the sun from the dark part of the room, even to the distance of 20 inches. I observed their motion was a little irregular, but rectilinear, and seemed accelerated as they approached the sun. These luminous globules appeared also on the other side of the spire, and preceded the sun, running out into the dark room, sometimes more, sometimes less, together, in the same manner as they followed the sun at its occultation. They appeared to be, in general, one-twentieth of an inch in diameter, and therefore must be very large, luminous globes in some part of the heavens, whose light was extinguished by that of the sun, so that they appeared not in open daylight; but whether of the meteor kind, or what sort of bodies they might be, I could not conjecture." Professor Hansteen mentions that, when employed in measuring the zenith distances of the pole star, he observed a somewhat similar phenomenon, which he described as "a luminous body which passed over the field of the universal telescope; that its motion was neither perfectly equal nor rectilinear, but resembled very much the unequal and somewhat serpentine motion of an ascending rocket;" and he concluded that it must have been "a meteor" or "shooting star" descending from the higher regions of the atmosphere. (See Edinburgh Philosophical Journal for April, 1825, No. XXIV.)

In my frequent observations on Venus, to determine the nearest positions to the sun in which that planet could be seen, I had several times an opportunity of witnessing similar phenomena. I was not a little surprised, when searching for the planet, frequently to perceive a body pass across the field of the telescope, apparently of the same size as Venus, though sometimes larger and sometimes smaller, so that I frequently mistook that body for the planet, till its rapid motion undeceived me. In several instances *four or five* of these bodies appeared to cross the field of view, sometimes in a perpendicular, and at other times

The following conclusions are deduced from the observations on Venus:

1. That this planet may be seen distinctly, with a moderate degree of magnifying power, *at the moment of its superior conjunction with the sun*, when its geocentric latitude, either north or south, at the time of conjunction, is not less than 1° 14′, or when the planet is about 58′ from the sun's limb. This conclusion is deduced from the observation of October 2, 1843,* stated above.

2. Another conclusion is, that during the space of 583 days, or about 19 months—the time this planet takes in moving from one conjunction with the sun to a like conjunction again—when its latitude at the time of its superior conjunction exceeds 1° 14′, it may be seen with an equatorial telescope every clear day without interruption, except about the period of its *inferior* conjunction, when its dark hemisphere is turned towards the earth, and a short time before and after it. When its geocentric latitude is less than 1° 14,′ it will be hid only about four days before, and the same time after its superior conjunction. During the same period it will be invisible to the naked eye, and consequently no observations can be made upon it with a common telescope for nearly six months, and sometimes more, according as its declination is north or south, namely, about two or three months before, and the same time after its superior conjunction, except where there is a very free and unconfined horizon. In regard

in a horizontal direction. They appeared to be luminous bodies, somewhat resembling the appearance of a planet when viewed in the daytime with a moderate magnifying power. Their motion was nearly rectilinear, but sometimes inclined to a waving or serpentine form, and they appeared to move with considerable rapidity—the telescope being furnished with a power of about 70 times. I was for a considerable time at a loss what opinion to form of the nature of these bodies; but, having occasion to continue these observations almost every clear day for nearly a twelvemonth, I had frequent opportunities of viewing this phenomenon in different aspects, and was at length enabled to form an opinion as to the cause of at least *some* of the appearances which presented themselves. In several instances, the bodies alluded to appeared much larger than usual, and to move with a more rapid velocity; in which case I could plainly perceive that they were nothing else than *birds* of different sizes, and apparently at different distances, the convex surface of whose bodies, in certain positions, strongly reflected the solar rays. In other instances, when they appeared smaller, their true shape was undistinguishable, by reason of their motion and their distance.

Having inserted a few remarks on this subject in No. xxv. of the Edinburgh Philosophical Journal for July, 1825, particularly in reference to Professor Hansteen's opinion, that article came under the review of M. Serres, sub-prefect of Embrun, in a paper inserted in the *Annales de Chimie* for October, 1825, entitled, "Notices regarding fiery meteors seen during the day." (See Edinburgh Philosophical Journal for July, 1826, p. 114.) In the discussion of this subject, M. Serres admits that the light reflected very obliquely from the feathers of a bird is capable of producing an effect similar to that which I have now described, but that "the explanation ought not to be *generalized*." He remarks, that while observing the sun at the repeating circle, he frequently perceived, even through the coloured glass adapted to the eyepiece, large luminous points which traversed the field of the telescope, and which appeared too well defined not to admit them to be distant, and subtended too large angles to imagine them birds. In illustration of this subject, he states the following facts: On the 7th of September, 1820, after having observed for some time the eclipse of the sun which happened on that day, he intended to take a walk in the fields, and on crossing the town, he saw a numerous group of individuals of every age and sex, who had their eyes fixed in the direction of the sun. Further on, he perceived another group, having their eyes in like manner turned towards the sun. He questioned an intelligent artist who was among them to learn the object that fixed his attention. He replied, "We are looking at the stars which are detaching themselves from the sun." "You may look yourself; that will be the shortest way to learn the fact." He looked, and saw, in fact, not stars, but balls of fire, of a diameter equal to the largest stars, which were projected in various directions from the upper hemisphere of the sun, with an incalculable velocity; and although this velocity of projection appeared the same in all, yet they did not all attain the same distance. These globes were projected at unequal and pretty short intervals. Several were often projected at once, but always diverging from one another. Some of them described a right line, and were extinguished in the distance: some described a parabolic line, and were in like manner extinguished; others, again, after having removed to a certain distance in a right line, retrograded upon the same line, and seemed to enter, still luminous, into the sun's disk. The ground of this magnificent picture was a sky-blue, somewhat tinged with brown. Such was his astonishment at the sight of so majestic a spectacle, that it was impossible for him to keep his eyes off it till it ceased, which happened gradually as the eclipse wore off and the solar rays resumed their ordinary lustre. It was remarked by one of the crowd that "the sun projected most stars at the time when it was palest;" and that the circumstance which first excited attention to this phenomenon was that of a woman, who cried out," Come here! come and see the flames that are issuing from the sun!"

I have stated the above facts because they may afterward tend to throw light upon certain objects or phenomena with which we are at present unacquainted. The phenomenon of "falling stars" has of late years excited considerable attention, and it seems now to be admitted that at least certain species of these bodies descend from regions far beyond the limits of our atmosphere. This may be pronounced as certain with regard to the "November Meteors." May not some of the phenomena described above be connected with the fall of meteoric stones—the showers of falling stars seen on the 12th and 13th of November, or other meteoric phenomena whose causes we have hitherto been unable to explain? Or, may we conceive that certain celestial bodies, with whose nature and destination we are as yet unacquainted, may be revolving in different courses in the regions around us, some of them opaque and others luminous, and whose light is undistinguishable by reason of the solar effulgence?

* For an explanation of the manner of viewing Venus at her superior conjunction, see "Celestial Scenery."

to the time in which this planet can be hid about the period of its *inferior* conjunction, I have ascertained from observation that it can never be hid longer than during a space of 2 days 22 hours, having seen Venus, about noon, like a fine, slender crescent, only 35 hours after she had passed the point of her inferior conjunction; and in a late instance she was seen when little more than a day from the period of conjunction. The longest time, therefore, that this planet can be hid from view during a period of 583 days, is only about ten days; and when its latitude at the time of the superior conjunction equals or exceeds 1° 14′, it can be hid little more than two days. This is a circumstance which cannot be affirmed of any other celestial body, the sun only excepted.

3. That every variation of the phases of this planet, from a slender crescent to a full, enlightened hemisphere, may, on every clear day, be conveniently exhibited by means of the equatorial telescope. This circumstance renders this instrument peculiarly useful in the instruction of the young in the principles of astronomy; for if the phase which Venus should exhibit at any particular time be known, the equatorial telescope may be directed to the planet, and its actual phase in the heavens be immediately exhibited to the astronomical pupil.

4. Since it is only at the period of the superior conjunction that this planet presents a full, enlightened hemisphere, and since it is only when this phase is presented that both its diameters can be measured, it is of some importance that observations be made on it at the moment of conjunction, by means of powerful telescopes furnished with micrometers, so as to determine the difference (if any) between its polar and equatorial diameters.

5. Another conclusion from the observations on Venus is, that a moderate diminution of the aperture of the object-glass of the telescope is useful, and even necessary, in viewing this planet when near the sun. Its effect is owing in part to the direct solar rays being thereby effectually excluded, for when these rays enter directly into the tube of the telescope, it is very difficult, and almost impossible, to perceive this planet, or any other celestial body when in the vicinity of the sun.

### *Observations on Jupiter and other Planets.*

This planet is very easily distinguished in the daytime with a very moderate magnifying power, when it is not within 30° or 35° of the sun. The following extract from my memorandums may serve as a specimen: May 12, 1813, $1^h$ $40^m$ P.M., saw Jupiter with a power of 15 times, the aperture not contracted. The planet appeared so distinct with this power that I have reason to believe it would have been perceived with a power of six or seven times. When the aperture was contracted to $\frac{6}{10}$ths of an inch, and afterward to half an inch, there was little perceptible difference in its appearance. It was then about 58° in longitude east of the sun.

Though Jupiter, when at a considerable distance from the sun, and near his opposition, appears to the naked eye with a brilliancy nearly equal to that of Venus, yet there is a very striking difference between them in respect of lustre when viewed in daylight. Jupiter, when viewed with a high magnifying power in the daytime, always exhibits a very dull, cloudy appearance, whereas Venus appears with a moderate degree of splendour. About the end of June, 1813, between five and six in the evening, having viewed the planet Venus, then within 20° of the sun, and which appeared with a moderate degree of lustre, I directed the telescope to Jupiter, at that time more than 32° from the sun, when the contrast between the two planets was very striking, Jupiter appearing so faint as to be just discernible, though his apparent magnitude was nearly double that of Venus. In this observation a power of 65 was used. In his approach towards the sun, about the end of July, I could not perceive him when he was within 16° or 17° of his conjunction with that luminary. *These circumstances furnish a sensible and popular proof,* independently of astronomical calculations, *that the planet Jupiter is placed at a much greater distance from the sun than Venus,* since its light is so faint as to be scarcely perceptible when more than 20 degrees from the sun, while that of Venus is distinctly seen amid the full splendour of the solar rays, when only about a degree from the margin of that luminary. With a power of 65 I have been enabled to distinguish the *belts* of Jupiter before sunset, but could never perceive any of his satellites till the sun was below the horizon. There are no observations which so sensibly and strikingly indicate the different degrees of light emitted by the different planets as those which are made in the daytime. To a common observer, during night, Jupiter and Venus appear, in a clear sky, nearly with equal brilliancy, and even Mars, when about the point of his *opposition* to the sun, appears with a lustre somewhat similar, though tinged with a ruddy hue; but when seen in daylight their aspect is very dissimilar. This circumstance evidently indicates, 1. That these planets are placed at different distances from the sun, and consequently are furnished with different degrees of light proportional to the square of their distances from that luminary; and, 2. That there are certain circumstances con-

nected with the surfaces and atmospheres of the planetary bodies which render the light they emit more or less intense, independently of their different distances from the central luminary; for Mars, though much nearer to the sun than Jupiter, is not so easily distinguished in the daytime, and even in the night time appears with a less degree of lustre.

My observations on *Saturn* in daylight have not been so frequent as those on Jupiter. I have been enabled to distinguish his ring several times before sunset with a power of 65, but his great southern declination, and consequent low altitude, at the periods when these observations were made, were unfavourable for determining the degree of his visibility in daylight; for a planet or a star is always more distinctly perceptible in a *high* than in a low altitude, on account of the superior purity of the atmosphere through which a celestial object is seen when at a high elevation above the horizon. This planet, however, is not nearly so distinctly visible in daylight as Jupiter, and I have chiefly seen it when the sun was not more than an hour or two above the horizon, but never at noonday, although it is probable that with powerful instruments it may be seen even at that period of the day. The planet *Mars* is seldom distinctly visible in the daytime, except when at no great distance from its opposition to the sun. The following is a memorandum of an observation on Mars, when in a favourable position: October 24, 1836, saw the planet Mars distinctly with a power of about 60, at 40 minutes past 9 A.M., the sun having been above the horizon nearly three hours. It appeared tolerably distinct, but scarcely so brilliant as a fixed star of the first magnitude, though with apparently as much light as Jupiter generally exhibits when viewed in daylight. It could not be traced longer at the time, so as to ascertain if it could be seen at midday, on account of the interposition of the western side of the window of the place of observation. The ruddy aspect of this planet —doubtless caused by a dense atmosphere with which it is environed—is one of the causes which prevents its appearing with brilliancy in the daytime. With respect to the planet *Mercury*, I have had opportunities of observing it several times after sunrise and before sunset, about 10 or 12 days before and after its greatest elongation from the sun, with a power of 45. I have several times searched for this planet about noon, but could not perceive it. The air, however, at the times alluded to, was not very clear, and I was not certain that it was within the field of of the telescope, and therefore I am not convinced but that, with a moderately high power, it may be seen even at noonday.

Such are some specimens of the observations I have made on the heavenly bodies in the daytime, and the conclusions which may be deduced from them. I have been induced to communicate them from the consideration that the most minute facts in relation to any science are worthy of being known, and may possibly be useful. They may at least gratify the astronomical tyro with some information which he will not find in the common treatises on Astronomy, and may perhaps excite him to prosecute a train of similar observations for confirming or correcting those which have been noted above.

Besides the deductions already stated, the following general conclusions may be noted: 1. That a celestial body may be as easily distinguished at noonday as at any time between the hours of nine in the morning and three in the afternoon, except during the short days in winter. 2. They are more easily distinguished at a high than at a low altitude—in the afternoon than in the morning, especially if their altitudes be low—and in the northern region of the heavens than in the southern. The difficulty of perceiving them at a low altitude is obviously owing to the thick vapours near the horizon. Their being less easily distinguished in the morning than in the afternoon is owing to the undulations of the atmosphere, which are generally greater in the morning than in the afternoon. This may be evidently perceived by looking at distant land objects at those times, in a hot day, through a telescope which magnifies about 40 or 50 times, when they will be found to appear tremulous and distorted in consequence of these undulations, especially if the sun be shining bright. In consequence of this circumstance, we can seldom use a high terrestrial power with effect on land objects except early in the morning and a short time before sunset. Their being more easily distinguished in the northern region of the heavens is owing to that part of the sky being of a deeper azure, on account of its being less enlightened than the southern with the splendour of the solar rays.

### *Utility of Celestial Day Observations.*

The observations on the heavenly bodies in the daytime, to which I have now directed the attention of the reader, are not to be considered as merely gratifications of a rational curiosity, but may be rendered subservient to the promotion of astronomical science. As to the planet Venus: when I consider the degree of brilliancy it exhibits, even in daylight, I am convinced that useful observations might frequently be made on its surface in the daytime, to determine some of its physical peculiarities and phenomena. Such observations might set at rest any disputes which

may still exist respecting the period of rotation of this planet. Cassini, from observations on a bright spot, which advanced 20° in 24 34$^m$, determined the time of its rotation to be 23 hours 20 minutes. On the other hand, Bianchini, from similar observations, concluded that its diurnal period was 24 days and 8 hours. The difficulty of deciding between these two opinions arises from the short time in which observations can be made on this planet, either before sunrise or after sunset, which prevents us from tracing with accuracy the progressive motion of its spots for a sufficient length of time; and, although an observer should mark the motion of the spots at he same hour on two succeeding evenings, and find they had moved forward 15° in 24 hours, he would still be at a loss to determine whether they had moved only 15° in all since the preceding observation, or had finished a revolution and 15° more. If, therefore, any spots could be perceived on the surface of Venus in the daytime, their motion might be traced, when she is in north declination, for 12 hours or more, which would completely settle the period of rotation. That it is not improbable that spots fitted for this purpose may be discovered on her disk in the daytime, appears from some of the observations of Cassini, who saw one of her spots when the sun was more than eight degrees above the horizon.* The most distinct and satisfactory views I have ever had of this planet were those which I obtained in the daytime, in summer, when it was viewed at a high altitude with a 44½ inch achromatic telescope, carrying a power of 150. I have at such times distinctly perceived the distincttion between the shade and colour of its margin and the superior lustre of its central parts, and some spots have occasionally been seen, though not so distinctly marked as to determine its rotation. Such distinct views are seldom to be obtained in the evening after sunset, on account of the undulations of the atmosphere, and the dense mass of vapours through which the celestial bodies are viewed when near the horizon.

Nor do I consider it altogether improbable that its *satellite* (if it have one, as some have supposed) may be detected in the daytime, when this planet is in a favourable position for such an observation, particularly when a pretty large portion of its enlightened surface is turned towards the earth, and when its satellite, of course, must present a similar phase. About the period of its greatest elongation from the sun, and soon after it assumes a crescent phase, in its approach to the inferior conjunction, may be considered as the most eligible times for prosecuting such observations. If this supposed satellite be about one-third or one-fourth of the diameter of its primary, as Cassini, Short, Baudouin, Montbarron, Montaigne, and other astronomers supposed, it must be nearly as large as Mercury, which has been frequently seen in daylight. If such a satellite have a real existence, and yet undistinguishable in daylight, its surface must be of a very different quality for reflecting the rays of light from that of its primary; for it is obvious to every one who has seen Venus with a high power in the daytime, that a body of equal brilliancy, though four times less in diameter, would be quite perceptible, and exhibit a visible disk. Such observations, however, would be made with much greater effect in Italy and other southern countries, and particularly in tropical climates, such as the southern parts of Asia and America, and in the West India islands, where the sky is more clear and serene, and where the planet may be viewed at higher altitudes and for a greater length of time, without the interruption of clouds, than in our island.

Again, the apparent magnitudes of the fixed stars, the quantity of light they respectively emit, and the precise class of magnitude which should be assigned to them, might be more accurately determined by day observations than by their appearance in the nocturnal sky. All the stars which are reckoned to belong to the *first magnitude* are not equally distinguishable in daylight. For example, the stars *Aldebaran* and *Procyon* are not so easily distinguished, nor do they appear with the same degree of lustre by day, as the stars *α Lyræ* and *Capella*. In like manner, the stars *Altair, Alphard, Deneb Ras Alhague*, considered as belonging to the *second* magnitude, are not equally distinguishable by the same aperture and magnifying power, which seems to indicate that a different quantity of light is emitted by these stars, arising from a difference either in their magnitude, their distance, or the quality of the light with which they are irradiated.

The following are likewise practical purposes to which celestial day observations may be applied. In accurately adjusting circular and transit instruments, it is useful, and even necessary, for determining the exact position of the meridian, to take observations of certain stars which differ greatly in zenith distance, and which transit the meridian nearly at the same time. But as the stars best situated for this purpose cannot, at every season, be seen in the evenings, we must, in certain cases, wait for several months before such observations can be made, unless we

* See Long's Astronomy, vol. ii. p. 487, and Encyclopodia Britannica, vol. ii. p. 436, 3d edition.

make them in the daytime, which can very easily be done if the instrument have a telescope adapted to it, furnished with such powers as those above stated, or higher powers if required. I have likewise made use of observations on the stars in the daytime for adjusting a clock or watch to mean time, when the sun was in a situation beyond the range of the instrument, or obscured by clouds, and when I did not choose to wait till the evening. This may, at first view, appear to some as paradoxical, since the finding of a star in daylight depends on our knowing its right ascension from the sun, and this last circumstance depends, in some measure, on our knowing the true time. But if a watch or clock is known not to have varied above seven or eight minutes from the time, a star of the first magnitude may easily be found by moving the telescope a little backward or forward till the star appear; and when it is once found, the exact variation of the movement is then ascertained by comparing the calculations which were previously necessary with the time pointed out by the nonius on the equatorial circle; or, in other words, by ascertaining the difference between the time assumed and the time indicated by the instrument when the star appears in the centre of the field of view. All this may be accomplished in five or six minutes.

Besides the practical purposes now stated, the equatorial telescope is perhaps the best instrument for instructing a learner in the various operations of practical astronomy, and particularly for enabling him to distinguish the names and positions of the principal stars; for when the right ascension and declination of any star is known from astronomical tables, the telescope may be immediately adjusted to point to it, which will infallibly prevent his mistaking one star for another. In this way, likewise, the precise position of the planet *Mercury*, *Uranus*, *Vesta*, *Juno*, *Ceres*, *Pallas*, a small comet, a nebula, a double star, or any other celestial body not easily distinguishable by the naked eye, may be readily pointed out, when its right ascension and declination are known to a near approximation.

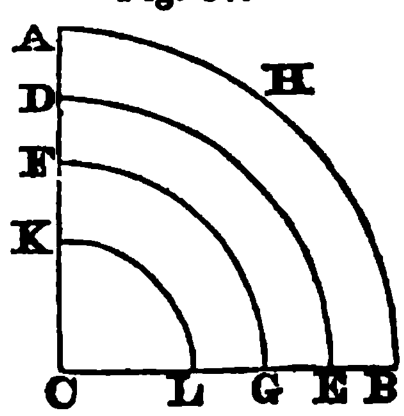
In conclusion, I cannot but express my surprise that the equatorial telescope is so little known, by many of the lovers of astronomical science. In several respectable academies in this part of Britain, and, if I am not misinformed, in most of our universities, this instrument is entirely unknown. This is the more unaccountable, as a small equatorial may be purchased for a moderate sum, and as there is no single instrument so well adapted for illustrating all the operations of practical astronomy. Where very great accuracy is not required, it may occasionally be made to serve the general purposes of a *transit instrument* for observing the passages of the sun and stars across the meridian. It may likewise be made to serve as a *theodolite* for surveying land and taking horizontal angles—as a *quadrant* for taking angles of altitude—as a *level*—as an *equal altitude instrument*—an *azimuth instrument* for ascertaining the sun's distance from the north or south points of the horizon—and as an accurate universal sundial, for finding the exact *mean* or *true* time on any occasion when the sun is visible. The manner of applying it to these different purposes will be obvious to every one who is in the least acquainted with the nature and construction of this instrument.

The price of a small equatorial instrument, such as that described p. 159, is about 16 guineas, exclusive of some of the eyepieces, which were afterward added for the purpose of making particular observations. Instruments of a larger size, and with more complicated machinery, sell from 50 to 100 guineas and upward. Messrs. W. and S. Jones, Holborn London, construct such instruments.

### ON THE QUADRANT.

Every circle being supposed to be divided into 360 equal parts or degrees, it is evident that 90 degrees, or the fourth part of a circle, will be sufficient to measure all angles between the horizon of any place and the line perpendicular to it which goes up to the zenith. Thus, in fig. 87, the line *C B* represents the plane of the horizon. *A C B H*, the quadrant; *A C*, the perpendicular to the horizon; and *A*, the zenith point. If the lines *B C* and *C A* represent a pair of compasses with the legs standing perpendicular to each other, and the curved lines *A B*, *D E*, and *F G*, the quarter of as many circles of different sizes, it is evident that although each of these differs from the others in size, yet that each contains the same portion of a circle, namely, a quadrant or fourth part; and thus it would be from the smallest to the largest quadrant that could be formed—they would all contain exactly 90 degrees each. By the application of this principle, the comparative measure of angles may be extended to an indefinite distance. By means of an instrument constructed in the form of a quadrant of a circle, with its curved edge divided into 90 equal parts, the altitude of any object in the heavens can at any time be determined.

Fig. 87.



There are various constructions of this instrument, some of them extremely simple, and others considerably complex and expensive, according to the degree of accuracy which the observations require. The following is a description of the *Pillar Quadrant*, as it was made by Mr. Bird for the Observatory of Greenwich, and several Continental observatories.

This instrument consists of a quadrant, *E E H G L* (fig. 88,) mounted on a pillar,

Fig. 88.

*B*, which is supported by a tripod, *A A*, resting on three foot-screws. The quadrant, the pillar, and the horizontal circle all revolve round a vertical axis. A telescope, *H*, is placed on the horizontal radius, and is directed to a meridian mark previously made on some distant object for placing the plane of the instrument in the meridian, and also for setting the zero, or beginning of the scale, truly horizontal. This is sometimes done by a level instead of a telescope, and sometimes by a plumb-line, *G*, suspended from near the centre, and brought to bisect a fine dot made on the limb, where a microscope is placed to examine the bisection. The weight or plummet at the end of the plumb-line is suspended in the cistern of water *b*, which keeps it from being agitated by the air. A similar dot is made for the upper end of the plumb-line upon a piece of brass, adjustable by a screw, *d*, in order that the line may be exactly at right angles to the telescope when it is placed at 0. The quadrant is screwed by the centre of its frame against a piece of brass, *e*, with three screws, and this piece is screwed to the top of the pillar *B* with other three screws. By means of the first three screws the plane of the quadrant can be placed exactly parallel to the vertical axis, and by the other screws the telescope *H* can be placed exactly perpendicular to it. The nut of the delicate screw *L* is attached to the end of the telescope *F* by a universal joint. The collar for the other end is jointed in the same manner to a clamp, which can be fastened to any part of the limb. A similar clamp-screw and slow motion is seen at *n* for the lower circle, which is intended to hold the circle fast and adjust its motion. The divisions of the lower, or horizontal circle, are read by verniers, or noniuses, fixed to the arms of the tripod at *l* and *m*; and, in some cases, three are used to obtain greater accuracy.

(890)

In using this quadrant, the axis of the telescope *H* is adjusted to a horizontal line, and the plane of the quadrant to a vertical line, by the means already stated. The screw of the clamp *L* is then loosened, and the telescope directed to the star or other object whose altitude is required. The clamp-screw being fixed, the observer looks through the telescope, and with the nut of the screw *L* he brings the telescope into a position where the star is bisected by the intersection of the wires in the field of the telescope. The divisions are then to be read off upon the vernier, and the altitude of the star will be obtained. By means of the horizontal circle *D*, all angles in the plane of the horizon may be accurately measured, such as the amplitudes and azimuths of the celestial bodies.

Quadrants of a more simple construction than the above may be occasionally used, such as Gunter's, Cole's, Sutton's, and others; but none of these is furnished with telescopes or telescopic sights, and therefore an altitude cannot be obtained by them with the same degree of accuracy as with that which has been now described.

By means of the quadrant, not only the altitudes of the heavenly bodies may be determined, but also the distances of objects on the earth by observations made at two stations; the altitude of fireballs and other meteors in the atmosphere; the height of a cloud, by observation on its altitude and velocity; and numerous other problems, the solution of which depends upon angular measurements. A *Mural Quadrant* is the name given to this instrument when it is fixed upon a wall of stone, and in the plane of the meridian, such as the quadrant which was erected by Flamstead in the Observatory at Green-

wich. Although the quadrant was formerly much used in astronomical observations, yet it may be proper to state that its use has now been almost completely superseded by the recent introduction of *Astronomical Circles*, of which we shall now give the reader a very short description, chiefly taken from Troughton's account of the instrument he constructed, as found in Sir D. Brewster's Supplement to Ferguson's Astronomy.

### THE ASTRONOMICAL CIRCLE.

An astronomical circle is a *complete circle* substituted in place of the quadrant, and differs from it only in the superior accuracy with which it enables the astronomer to make his observations. The large vertical or declination circle *C C* (fig. 89) is composed of two

Fig. 89.

complete circles, strengthened by an edge-bar on their inside, and firmly united at their extreme borders by a number of short braces or bars, which stand perpendicular between them, and which keep them at such a distance as to admit the achromatic telescope *T T*. This double circle is supported by 16 conical bars, firmly united, along with the telescope to a horizontal axis. The exterior limb of each circle is divided into degrees and parts of a degree, and these divisions are divided into seconds by means of the micrometer microscopes *m m*, which read off the angle on opposite sides of each circle. The cross wires in each microscope may be moved over the limb till they coincide with the nearest division of the limb, by means of the micrometer screws *c c*, and the space moved through is ascertained by the divisions on the graduated head above *c*, assisted by a scale within the microscope. The microscopes are supported by two arms proceeding from a small circle concentric with the horizontal axis, and fixed to the vertical columns. This circle is the centre upon which they can turn round nearly a quadrant for the purpose of employing a new portion of the divisions of the circle, when it is reckoned prudent to repeat any delicate observations upon any part of the limb. At *h* is represented a level for placing the axis in a true horizontal line, and at *k* is fixed another level parallel to the telescope for bringing the zero of the divisions to a horizontal position. The horizontal axis to which the vertical circle and the telescope are fixed is equal in length to the distance between the vertical pillars, and its pivots are supported by semicircular bearings placed at the top of each pillar. These two vertical pillars are firmly united at their bases to a crossbar, *f*. To this crossbar is also fixed a vertical axis about three feet long, the lower end of which, terminating in an obtuse point, rests in a brass conical socket firmly fastened at the bottom of the hollow in the stone pedestal *D*, which receives the vertical axis. This socket supports the whole weight of the movable part of the instrument. The upper part of the vertical axis is supported by two pieces of brass, one of which is seen at *e*, screwed to the ring *i*, and containing a right angle, or *Y*. At each side of the ring, opposite to the points of contact, is placed a tube containing a heliacal spring, which, by a constant pressure on the axis, keeps it against its bearings, and permits it to turn, in these four points of contact, with an easy and steady motion. The two bearings are fixed upon two rings capable of a lateral adjustment; the lower one by the screw *d* to incline the axis to the east or west, while the screw *b* gives the upper one, *i*, a motion in the plane of the meridian. By this means the axis may be adjusted to a perpendicular position as exactly as by the usual method of the tripod with foot-screws. These rings are attached to the centre-piece *s*, which is firmly connected with the upper surface of the stone by six conical tubes *A*, *A*, *A*, &c., and brass standards at every angle of the pedestal. Below this frame lies the azimuth circle, *E E*, consisting of a circular limb, strengthened by

ten hollow cones firmly united with the vertical axis, and consequently turning freely along with it. The azimuth circle, $E$ $E$, is divided and read off in the same manner as the vertical circle. The arms of the microscopes, $B$ $B$, project from the ring $i$, and the microscopes themselves are adjustable by screws, to bring them to zero and to the diameter of the circle. A little above the ring $i$ is fixed an arm, $L$, which embraces and holds fast the vertical axis with the aid of a clamp-screw. The arm $L$ is connected at the extremity with one of the arms $A$, by means of the screw $a$, so that by turning this screw a slow motion is communicated to the vertical axis and the azimuth circle.

In order to place the instrument in a true vertical position, a plumb-line, made of fine silver wire, is suspended from a small hook at the top of the vertical tube $n$, connected by braces with one of the large pillars. The plumb-line passes through an angle in which it rests, and by means of a screw may be brought into the axis of the tube. The plummet at the lower end of the line is immersed in a cistern of water, $t$, in order to check its oscillations, and is supported on a shelf proceeding from one of the pillars. At the lower end of the tube $n$ are fixed two microscopes, $o$ and $p$, at right angles to one another, and opposite to each is placed a small tube containing a lucid point. The plumb-line is then brought into such a position by the screws $d$ $b$, and by altering the suspension of the plumb-line itself, that the image of the luminous point, like the disk of a planet is formed on the plumb-line, and accurately bisected by it. The vertical axis is then turned round, and the plumb-line examined in some other position. If it still bisects the luminous point, the instrument is truly vertical; but if it does not, one half of the deviation must be corrected by the screws $d$ $b$, and the other half by altering the suspension of the line till the bisection of the circular image is perfect in every position of the instrument.

It is not many years since circular repeating instruments came into general use. The principle on which the construction of a repeating circle is founded appears to have been first suggested by Professor Mayer, of Gottingen, in 1758; but the first person who applied this principle to measure round the limb of a divided instrument was Borda, who about the year 1789, caused a repeating circle to be constructed that would measure with equal facility horizontal and vertical angles. Afterward Mr. Troughton greatly improved the construction of Borda's instrument by the introduction of several contrivances, which insure, at the same time, its superior accuracy and convenience in use; and his instruments have been introduced into numerous observatories. Circular instruments, on a large scale, have been placed in the Royal Observatory of Greenwich, and in most of the principal observatories on the Continent of Europe. Although it is agreed on all hands that greater accuracy may be obtained by a repeating circle than by any other having the same radius, yet there are some objections to its use which do not apply to the altitude and azimuth circle. The following are the principal objections, as stated in vol. i. of the "Memoirs of the Astronomical Society of London:" 1. The origin of the repeating circle is due to *bad dividing* which ought not to be tolerated in any instrument in the present state of the art. 2. There are three sources of fixed error which cannot be exterminated, as they depend more on the materials than on the wormanship; first, the zero of the level changes with variations of temperature; secondly, the resistance of the centre work to the action of the tangent screws; and, thirdly, the imperfection of the screws in producing motion and in securing permanent positions. 3. The instrument is applied with most advantage to slowly moving or circumpolar stars; but in low altitudes these stars are seen near the horizon, where refraction interferes. 4. Much time and labour are expended, first in making the observations, and again in reducing them. 5. When any one step in a series of observations is bad, the whole time and labour are absolutely lost. 6. When the instrument has a telescope of small power, the observations are charged with errors of vision which the repeating circle will not cure. 7. This instrument cannot be used as a transit instrument, nor for finding the exact meridian of a place.

A great variety of directions is necessary in order to enable the student of practical astronomy thoroughly to understand and to apply this instrument to practice, which the limited nature of the present work prevents us from detailing. As this instrument consists of a variety of complicated pieces of machinery, it is necessarily somewhat expensive. A six-inch brass astronomical circle for altitudes, zenith or polar distances, azimuths, with achromatic telescopes, &c., is marked in Messrs. W. and S. Jones's catalogue of astronomical instruments at £27 6s. A circle 12 inches in diameter, from £36 15s. to £68 5s. An 18 inch ditto, of the best construction, £105. The larger astronomical circles for public observatories, from 100 to 1000 guineas and upward, according to their size, and the peculiarity of their construction.

## THE TRANSIT INSTRUMENT.

A transit instrument is intended for observing celestial objects as they pass across the meridian. It consits of a telescope fixed at right angles to a horizontal axis, which axis must be so supported that what is called *the line of collimation*, or the line of sight of the telescope, may move in the plane of the meridian. This instrument was first invented by Romer in the year 1689, but has since received great improvements by Troughton, Jones, and other modern artists. Transit instruments may be divided into two classes, *Portable* and *Fixed*. The portable instrument, when placed truly in the meridian, and well adjusted, may be advantageously used as a stationary instrument in an observatory, if its dimensions be such as to admit of a telescope of 3½ feet focal length; but when the main tube is only from 20 to 30 inches long, with a proportional aperture, it is more suited for a travelling instrument to give the exact time; and, when carried on board a ship in a voyage of discovery, may be taken on shore at any convenient place for determining the solar time of that place, and for correcting the daily rate of the chronometer, giving the time at the first meridian, so that the longitude of the place of observation may be obtained from the difference of the observed and indicated times, after the proper corrections have been made.

The following is a brief description of one of Mr. Troughton's portable transit instruments. In fig. 90, *P P* is an achromatic telescope firmly fixed by the middle to a double conical and horizontal axis *H H*, the pivots of which rest on angular bearings called *Y's*, at the top of the standards *B B*, rendered steady by oblique braces *D D*, fastened to the central part of the circle *A A*. In large fixed instruments, the pivots and angular bearings are supported on two massive stone pillars, sunk several feet into the ground, and are sometimes supported by mason-work, to secure perfect stability. The axis *H H* has two adjustments, one for making it exactly level, and the other for placing the telescope in the meridian. A graduated circle, *L*, is fixed to the extremity of the pivot, which extends beyond one of the *Y's* and the two radii that carry the verniers, *a a*, are fitted to the extremities of the pivot in such a way as to turn round independent of the axis. The double verniers have a small level attached to them, and a third arm, *b*, which is connected with the standard *B* by means of a screw, *s*. If the verniers are placed, by means of the level, in a true horizontal position, when the axis of the telescope is horizontal, and the arm *b* screwed by the screw *s* to the standard B, the

Fig. 90.

verniers will always read off the inclination of the telescope, and will enable the observer to point it to any star by means of its meridian altitude. The whole instrument rests on three foot-screws entered into the circle *A A*. In the field of view of the telescope there are several parallel vertical wires, crossed at right angles with a horizontal one, and the telescope is sometimes furnished with a diagonal eyepiece for observing stars near the zenith. A level likewise generally accompanies the instrument, in order to place it horizontal by being applied to the pivots of the axis.

In order to fix the transit instrument exactly in the meridian, a good clock regulated to sidereal time is necessary. This regulation may be effected by taking equal altitudes of the sun or a star before and after they pass the meridian, which may be done by small quadrants or by a good sextant. The axis *H* of the instrument is then to be placed horizontal by a spirit level, which accompanies the transit, and the greatest care must be taken that the axis of vision describes in the heavens a great circle of the sphere. To ascertain whether the telescope be in the plane of the meridian, observe by the clock when a circumpolar star seen through the telescope transits both above and below the pole, and if the times of describing the eastern and western parts of its circuit be equal, the telescope is then in the plane of the meridian; otherwise, certain adjustments must be made. When

the telescope is at length perfectly adjusted, a landmark must be fixed upon at a considerable distance, the greater the better. This mark must be in the horizontal direction of the intersection of the cross wires, and in a place where it can be illuminated, if possible, in the nighttime, by a lantern hanging near it; which mark being on a fixed object, will serve at all times afterward for examining the position of the telescope.

Various observations and adjustments are requisite in order to fixing a transit instrument exactly in the plane of the meridian. There is the adjustment of the *level;* the horizontal adjustment of the axis of the telescope; the placing of the parallel lines in the focus of the eyeglass, so as to be truly vertical, and to determine the equatorial value of their intervals; the collimation in *azimuth*, so that a line passing from the middle vertical line to the optical centre of the object-glass is at right angles with the axis of the telescope's motion; the collimation in *altitude*, so that the horizontal line should cross the parallel vertical lines, not only at right angles, but also in the optical centre of the field of view, with various other particulars, but of which our limited space will not permit us to enter into details. Those who wish to enter into all the minute details in reference to the construction and practical application of this and the other instruments above described, as well as all the other instruments used by the practical astronomer, will find ample satisfaction in perusing the Rev. Dr. Pearson's Introduction to Practical Astronomy, 4to, vol. ii.

A portable transit instrument, with a cast-iron stand, the axis 12 inches in length, and the achromatic telescope about 20 inches, packed in a case, sells at about 16 guineas; with a brass-framed stand and other additions, at about 20 guineas. Transit instruments of larger dimensions are higher in proportion to their size, &c.

## CHAPTER III.

### *On Observatories.*

In order to make observations with convenience and effect on the heavenly bodies, it is expedient that an *observatory*, or place for making the requisite observations, be erected in a proper situation. The following are some of the leading features of spot adapted for making celestial observations: 1. It should command an extensive visible horizon all around, particularly towards the south and the north. 2. It should be a little elevated above surrounding objects. 3. It should be, if possible, at a considerable distance from manufactories, and other objects which emit much smoke or vapour, and even from chimney-tops where no sensible smoke is emitted, as the heated air from the top of funnels causes undulations in the atmosphere. 4. It should be at a distance from swampy ground or valleys that are liable to be covered with fogs and exhalations. 5. It should not, if possible, be too near public roads, particularly if paved with stones, and frequented by heavy carriages, as in such situations undulations and tremulous motions may be produced injurious to the making of accurate observations with graduated instruments. 6. It is expedient that the astronomical observer should have access to some distant field within a mile of the observatory, on which a meridian mark may be fixed after his graduated instruments are properly adjusted. The distance at which a meridian mark should be erected will depend in part on the focal length of the telescope generally used for making observations on the right ascensions and declinations of the stars. It should be fixed at such a distance that the mark may be distinctly seen without altering the focus of the telescope when adjusted to the sun or stars, which, in most cases, will require to be at least half a mile from the place of observation, and more if it can be obtained.

Observatories may be distinguished into public and private. A *private* observatory may be comprehended in a comparatively small building, or in the wing of a building of ordinary dimensions for a family, provided the situation is adapted to it. Most of our densely-peopled towns and cities, which abound in narrow streets and lanes, are generally unfit for good observatories, unless at an elevated position at their extremities. Public observatories, where a great variety of instruments is used, and where different observers are employed, require buildings of larger dimensions, divided into a considerable number of apartments. The Observatory of *Greenwich* is composed principally of two separate buildings, one of which is the observatory properly so called, where the assistant lives and makes all his observations; the other is the dwelling-house in which the astronomer royal resides. The former consists of three rooms on the ground-floor, the middle of which is the assistant's sitting and calculating room, furnished with a small library of such books only as are necessary for his computa-

tions, and an accurate clock made by the celebrated Graham, which once served Dr. Halley as a transit clock. Immediately over this is the assistant's bedroom, with an alarum to awake him to make his observations at the proper time. The room on the eastern side of this is called the *transit*-room, in which is an eight-feet transit instrument, with an axis of three feet, resting on two pieces of stone, made by Mr. Bird, but successively improved by Messrs. Dollond, Troughton, and others. Here is also a chair to observe with, the back of which lets down to any degree of elevation that convenience may require. On the western side is the *quadrant-room*, with a stone pier in the middle running north and south, having on its eastern face a mural quadrant of eight feet radius, by which observations are made on the southern quarter of the meridian, through an opening in the roof of three feet wide, produced by means of two sliding shutters. On the western face is another mural quadrant of eight feet radius, the frame of which is of iron and the arch of brass, which is occasionally applied to the north quarter of the meridian. In the same room is the famous zenith sector, twelve feet long, with which Dr. Bradley made the observations which led to the discovery of the nutation of the earth's axis and the aberration of the light of the fixed stars. Here are also Dr. Hooke's reflecting quadrant, and three time-keepers by Harrison. On the south side of this room a small wooden building is erected for the purpose of observing the eclipses of Jupiter's satellites, occultations of stars by the moon, and other phenomena which require merely the use of a telescope, and the true or mean time. It is furnished with sliding shutters on the roof and sides to view any part of the hemisphere from the prime vertical down to the southern horizon. It contains a forty-inch achromatic with a triple object-glass, and also a five-feet achromatic by Messrs. John and Peter Dollond, a two-feet reflecting telescope by Edwards, and a six-feet reflector by Herschel. Above the dwelling-house is a large octagonal room, which is made the repository for certain old instruments, and for those which are too large to be used in the other apartments. Among many other instruments, it contains an excellent ten-feet achromatic by Dollond, and a six-feet reflector by Short. Upon a platform, in an open space, is erected the great reflecting telescope constructed by Mr. Ramage of Aberdeen, on the Herschelian principle, which has a speculum of 15 inches diameter and 25 feet focal length, remarkable for the great accuracy and brilliancy with which it exhibits celestial objects. Various other instruments of a large size and of modern construction have of late years been introduced into this observatory, such as the large and splendid transit instrument constructed by Troughton in 1816, the two large *mural* circles by Troughton and Jones, the transit clock by Mr. Hardy, and several other instruments and apparatus which it would be too tedious to enumerate and describe.

Every observatory, whether public or private, should be furnished with the following instruments: 1. A transit instrument for observing the meridian passage of the sun, planets, and stars. 2. A good clock, whose accuracy may be depended upon. 3. An achromatic telescope of at least 44 inches focal distance, with powers of from 45 to 180, for viewing planetary and other phenomena; or a good reflecting telescope at least three feet long, and the speculum five inches in diameter. 4. An equatorial instrument, for viewing the stars and planets in the daytime, and for finding the right ascension and declination of a comet, or any other celestial phenomenon. Where this instrument is possessed, and in cases where no great degree of accuracy is required, the equatorial may be made to serve the general purposes of a transit instrument.

A private observatory might be constructed in any house which has a commanding view of the heavens, provided there is an apartment in it in which windows may be placed, or openings cut out fronting the north, the south, the east, and the west. The author of this work has a small observatory erected on the top of his house, which commands a view of 20 miles towards the east, 30 miles towards the west and north-west, and about 20 miles towards the south, at an elevation of more than 200 feet above the level of the sea and the banks of the Tay, which are about half a mile distant. The apartment is 12½ feet long by 8½ wide, and 8½ feet between the floor and the roof. It has an opening on the north, by which observations can be made on the pole star; a window on the south, by which the meridian passages of the heavenly bodies may be observed; another opening towards the east, and a fourth opening, consisting of a door, towards the west. There is a pavement of lead on the outside, all around the observatory-room, inclosed by a stone parapet 3½ feet high, the upper part of which is coped with broad flat stones, in certain parts of which grooves or indentations are made for receiving the feet of the pedestal of an achromatic telescope, which form a steady support for the telescope in the open air, when the weather is calm and serene, and when observations are intended to be made on any region of the heavens. By placing an instrument on this parapet, it may be directed to any point of the celestial canopy

except a small portion near the northern horizon, which is partly intercepted by a small hill. In the following ground plan, fig. 91, *A A A* is the parapet surrounding the observatory room; *B B B*, a walk around it nearly three feet broad, covered with lead. *O* is the apartment for the observatory, having an opening, *C*, to the north; another opening, *D*, to the east, *E* is a window which fronts

Fig. 91.

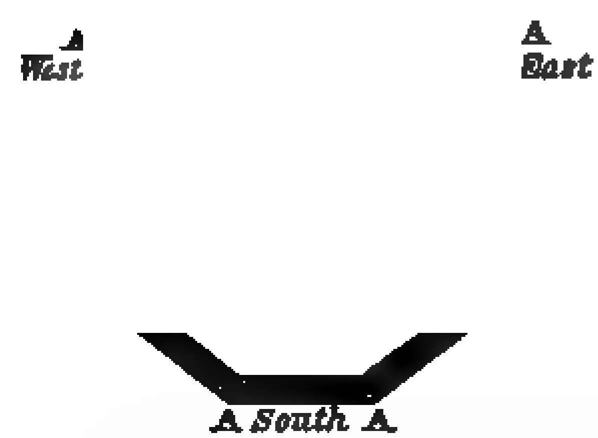



Fig. 92.

the south, and *F* is a door fronting the west, by which an access is obtained to the open area on the outside. *G H I* is an area on the outside towards the south, covered with lead, 15 feet long from *G* to *H*, and 6½ feet from *E* to *I*, from which a commanding view of the southern, eastern, and western portions of the heavens may be obtained: *e e e e* are positions on the top of the parapet where a telescope may be conveniently placed, when observations are intended to be made in the open air. The top of this parapet is elevated about 30 feet from the level of the ground. On the roof of the observatory, about 12 feet above its floor, on the outside, is a platform of lead, surrounded by a railing six feet by five, with a seat, on which observations either on celestial or terrestrial objects may occasionally be made. *K* is a door or hatchway, which forms an entrance into the observatory from the apartments below, which folds down, and forms a portion of the floor.

In public observations, where zenith or polar distances require to be measured, it is necessary that there should be a dome, with an opening across the roof, and down the north and south walls. Should an altitude or azimuth circle, or an equatorial instrument be used, they will require a revolving roof with openings and doors on two opposite sides, to enable an observer to follow a heavenly body across all the cardinal points. The openings may be about 15 inches wide, and the roof need not be larger than what is requisite for giving room to the observer and the instrument, lest its bulk and weight should impede its easy motion. There have been various plans adopted for revolving domes. Fig. 92 represents a section of the rotatory dome constructed at East Sheen by the Rev. Dr. Pearson. This dome turns round on three detached spheres of lignum vitæ, in a circular bed, formed partly by the dome, and partly by the cylindrical framework which surrounds the circular room of nine feet diameter. A section of this bed forms a square which the sphere just fills, so as to have a small play to allow for shrinking; and, when this dome is carried round, the spheres, having exactly equal diameters of 4½ inches each, when placed at equal distances from one another, keep their relative places, and move together in a beautifully smooth manner. These spheres act as friction rollers in two directions at the four points of contact, in case any obstacle is opposed to their progressive motion by the admission of dirt, or by any change of figure of the wood that composes the rings of the dome and of the gangway. No groove is here made but what the weight of the roof resting on the hard sphere occasions. The dome itself moves twice round for the balls once, and has, in this way, its friction diminished. The wood of this dome is covered by Wyatt's patent copper, one square foot of which weighs upward of a pound; and the copper is so turned over the nails that fix it at the parts of junction that not a single nail is seen in the whole dome. This covering is intended to render the dome more permanent than if it had been made of wood alone. At the observatory at Cambridge the dome is made chiefly of iron. In

the figure, $a$ $a$ represents one of the two oblong doors that meet at the apex of the cone, and a piece of sheet-copper, bent over the upper end of the door which shuts last, keeps the rain from entering at the place of junction. The two halves of the dome are united by brass rods passing through the door-cheeks of wainscot at $a$ and $a$ by means of nuts that screw upon their ends, which union allows the dome to be separated into two parts when there may be occasion to displace it. The wooden plate $b$ $b$, which appears in a straight line, is a circular broad ring, to which the covering wainscot boards are made fast above the eaves, and $c$ $c$ is a similar ring forming the wall-plate or gangway on which the dome rests and revolves.

Fig. 92.*

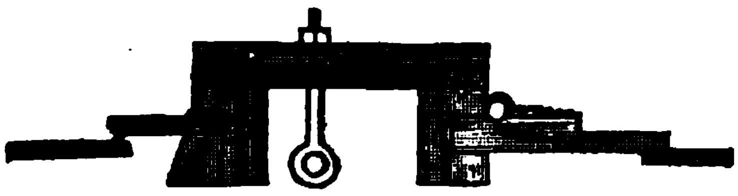


Fig. 92* shows a small door that lies over the summit of the dome, and may be separately opened for zenith observations; the rod of metal, with a ring at the lower end passing through it, serves to open and shut this door, and at the same time carries upon its upper end a large ball, which falls back on the roof when the door is open, and keeps the door in a situation to be acted upon by the hook of a handle that is used for this purpose. The doors $a$ $a$, being curved, are made to open in two halves, the upper one being opened first, on account of its covering the end of the other; and the observer may open one or two doors, as may best suit his purpose. The weight of this dome is such that a couple of wedges, inserted by a gentle blow between the rings $b$ $b$ and $c$ $c$, will keep it in its situation under the influence of the strongest wind.

It may not be improper to remark, that in all observatories, and in every apartment where celestial observations are made, there should, if possible, be a uniform temperature; and, consequently, a fire should never be kept in such places, particularly when observations are intended to be made, as it would cause currents of air through the doors and other openings which would be injurious to the accuracy of observations. When a window is opened in an ordinary apartment where a fire is kept, there is a current of heated air which rushes out at the top, and a current of cold air which rushes in from below, producing agitations and undulations which prevent even a good telescope from showing celestial objects distinct and well defined; and I have no doubt that many young observers have been disappointed in their views of celestial phenomena from this circumstance, when viewing the heavenly bodies from heated rooms in cold winter evenings, as the aerial undulations before the telescope prevent distinct vision of such objects as the belts of Jupiter, the spots of Mars, and the rings of Saturn.

## CHAPTER IV.

### *On Orreries or Planetariums.*

An orrery is a machine for representing the order, the motions, the phases, and other phenomena of the planets. Although orreries and planetariums are not so much in use as they were half a century ago, yet, as they tend to assist the conceptions of the astronomical tyro in regard to the motions, order, and positions of the bodies which compose the solar system, it may not be inexpedient shortly to describe the principles and construction of some of these machines.

The reason why the name *Orrery* was at first given to such machines is said to have been owing to the following circumstance: Mr. Rowley, a mathematical instrument-maker, having got one from Mr. George Graham, the original inventor, to be sent abroad with some of his own instruments, he copied it, and made the first for the Earl of Orrery. Sir R. Steele, who knew nothing of Mr. Graham's machine, thinking to do justice to the first encourager, as well as to the inventor of such a curious instrument, called it an *Orrery*, and gave Mr. Rowley the praise due to Mr. Graham. The construction of such machines is not a modern invention. The hollow sphere of Archimedes was a piece of mechanism of this kind, having been intended to exhibit the motions of the sun, the moon, and the five planets according to the Ptolemaic system. The next orrery of which we have any account was that of Posidonius, who lived about 80 years before the Christian era, of which Cicero says, "If any man should carry the sphere of Posidonius into Scythia or Britain, in every revolution of which the motions of the sun, moon, and five planets were the same as in the heavens each day and night, who in those barbarous countries could doubt of its being finished, not to say actuated,

by perfect reason?" The next machine of this kind which history records was constructed by the celebrated Boëthius, the Christian philosopher, about the year of Christ 510, of which it was said "that it was a machine pregnant with the universe—a portable heaven —a compendium of all things." After this period we find no instances of such mechanism of any note till the 16th century, when science began to revive and the arts to flourish. About this time the curious clock in Hampton Court Palace was constructed, which shows not only the hours of the day, but the motions of the sun and moon through all the signs of the zodiac, and other celestial phenomena. Another piece of mechanism of a similar kind is the clock in the Cathedral of Strasburg, in which, besides the clock part, is a celestial globe or sphere with the motions of the sun, moon, planets, and the firmament of the fixed stars, which was finished in 1574.

Among the largest and most useful pieces of machinery of this kind is the great sphere erected by Dr. Long, in Pembroke Hall, in Cambridge. This machine, which he called the *Uranium*, consists of a planetarium, which exhibits the motion of the earth and the primary planets, the sun, and the motion of the moon round the earth, all inclosed within a sphere. Upon the sphere, besides the principal circles of the celestial globe, the zodiac is placed, of a breadth sufficient to contain the apparent path of the moon, with all the stars over which the moon can pass; also the ecliptic, and the heliocentric orbits of all the planets. The Earth in the planetarium has a movable horizon, to which a large movable brass circle within the sphere may be set coincident, representing the plane of the horizon continued to the starry heavens. The horizons, being turned round, sink below the stars on the east side, and make them appear to rise, and rise above the stars on the west side, and make them appear to set. On the other hand, the earth and the horizon being at rest, the sphere may be turned round to represent the apparent diurnal motion of the heavens. In order to complete his idea on a large scale, the doctor erected a sphere of 18 feet diameter, in which above 30 persons might sit conveniently, the entrance to which is over the south pole by six steps. The frame of the sphere consists of a number of iron meridians, the northern ends of which are screwed to a large round plate of brass with a hole in the centre of it; through this hole, from a beam in the ceiling, comes the north pole, a round iron rod about three inches long, and which supports the upper part of the sphere to its proper elevation for the latitude of Cambridge, so much of it as is invisible in England being cut off, and the lower or southern ends of the meridians terminate on, and are screwed down to, a strong circle of oak 13 feet in diameter, which, when the sphere is put in motion, runs upon large rollers of lignum vitæ, in the manner that the tops of some windmills turn round. Upon the iron meridians is fixed a zodiac of tin painted blue, on which the ecliptic and heliocentric orbits of the planets are drawn, and the stars and constellations traced. The whole is turned round with a small winch, with as little labour as it takes to wind up a jack, although the weight of iron, tin, and the wooden circle is above a thousand pounds. This machine, though now somewhat neglected, may still be seen in Pembroke Hall, Cambridge, where I had an opportunity of inspecting it in November, 1839. The essential parts of the machine still remain nearly in the same state as when originally constructed in 1758.

The machine which I shall now describe is of a much smaller and less complex description than that which has been noticed above, and may be made for a comparatively small expense, while it exhibits with sufficient accuracy the motions, phases, and positions of all the primary planets, with the exception of the new planets, which cannot be accurately represented on account of their orbits crossing each other. In order to the construction of the planetarium to which I allude, we must compare the proportion which the annual revolutions of the primary planets bear to that of the Earth. This proportion is expressed in the following table, in which the first column is the time of the Earth's period in days; the second, that of the planets; and the third and fourth are numbers very nearly in the same proportion to each other:

| | | | | | | |
|---|---|---|---|---|---|---|
| 365¼ | : | 88 | : : 83 | : | 20 | for Mercury. |
| 365¼ | : | 224⅔ | : : 52 | : | 32 | for Venus. |
| 365¼ | : | 687 | : : 40 | : | 75 | for Mars. |
| 365¼ | : | 4332½ | : : 7 | : | 83 | for Jupiter. |
| 365¼ | : | 10759¼ | : : 5 | : | 148 | for Saturn. |
| 365¼ | : | 30686 | : : 3 | : | 253 | for Uranus. |

On account of the number of teeth required for the wheel which moves Uranus, it is frequently omitted in planetariums, or the planet is placed upon the arbour which supports Saturn. If we now suppose a spindle or arbour with six wheels *fixed* upon it in a horizontal position, having the number of teeth in each corresponding to the numbers in the third column, namely, the wheel *A M* (fig. 93) of 83 teeth, *B L* of 52, *C K* of 50, for the earth, *D I* of 40, *E H* of 7, and *F G* of 5; and another set of wheels moving freely about an arbour having the number of teeth in the fourth column, namely, *A N* of 20, *B O* of 32, *C P* of 50, for the earth, *D Q* of 75, *E R* of 83, and *F S* of 148 then, if these two

arbours of fixed and movable wheels be made of the size and fixed at the distance here re-

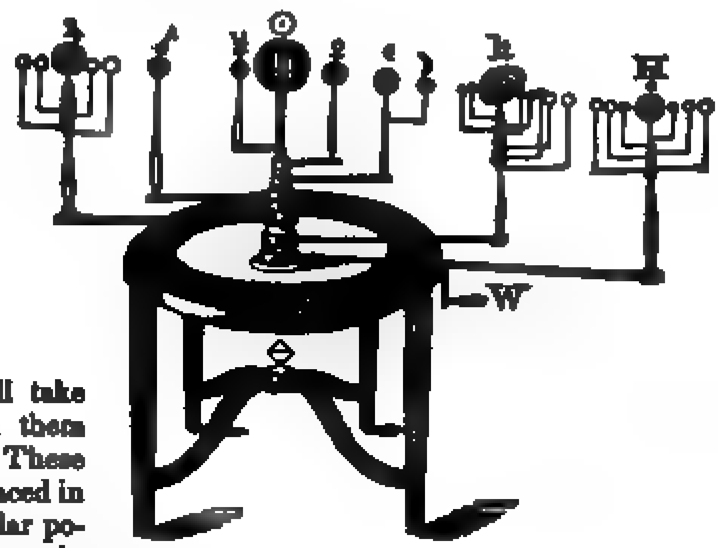
Fig. 93.

presented, the teeth of the former will take hold of those of the latter, and turn them freely when the machine is in motion. These arbours, with their wheels, are to be placed in a box of a proper size, in a perpendicular position; the arbour of fixed wheels to move in pivots at the top and bottom of the box, and the arbour of the movable wheels to go through the top of the box, and having on the top a wire fixed, and bent at a proper distance into a right angle upward, bearing on the top a small round ball representing its proper planet. If, then, on the lower part of the arbour of fixed wheels be placed a pinion of screw-teeth, a winch turning a spindle with an endless screw, playing in the teeth of the arbour, will turn it with all its wheels, and these wheels will turn the others about, with their planets, in their proper and respective periods of time; for while the fixed wheel *C K* moves its equal *C P* once round, the wheel *A M* will move *A N* a little more than four times round, and will consequently exhibit the motion of Mercury; the wheel *E H* will turn the wheel *E R* about $\frac{1}{12}$th round, representing the proportional motion of Jupiter; and the wheel *F G* will turn the wheel *F S* about $\frac{1}{29.5}$th round, and represent the motion of Saturn, and so of all the rest.

The following figure (fig. 94) represents the appearance of the instrument when completed. Upon the upper part of the circular box is pasted a zodiac circle divided into 12 signs, and each sign into 30 degrees, with the corresponding days of the month. The wheel-work is understood to be within the box, which may either be supported by a tripod, or with four feet, as here represented. The moon and the satellites of Jupiter, Saturn, and Uranus, are movable only by the hand. When the winch *W* is turned, then all the primary planets are made to move in their respective velocities. The ball in the centre represents the Sun, which is either made of brass, or of wood gilded with gold.

By this planetarium, simple as its construction may appear, a variety of interesting

Fig. 94.



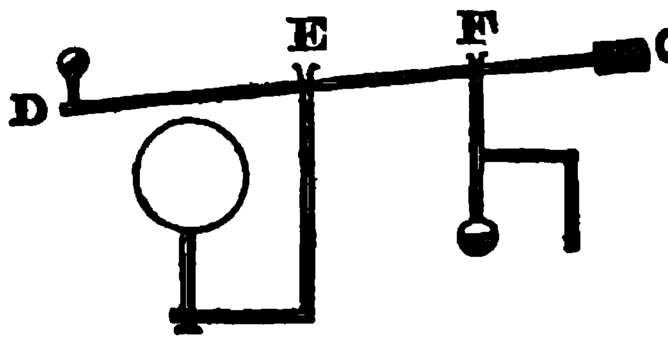

exhibitions may be made and problems performed, which may be conducive to the instruction of young students of Astronomy. I shall mention only a few of these as specimens.

1. When the planets are placed in their respective positions by means of an ephemeris or the Nautical Almanac, the relative positions of those bodies in respect to each other, the quarters of the heavens where they may be observed, and whether they are to be seen in the morning before sunrise or in the evening after sunset, may be at once determined. For example, on the 19th of December, 1844, the *heliocentric* places of the planets are as follows: Uranus, 2° of Aries; Saturn, 8° 24′ of Aquarius; Jupiter, 7° 4′ of Aries; Mars, 12° 45′ of Libra; the Earth, 27° 46′ of Gemini; Venus, 29° 46′ of Virgo, Mercury, 7° 53′ of Pisces. When the planets are placed on the planetarium in these positions, and the eye placed in a line with the balls representing the Earth and the Sun, all those situated to the left of the sun are to the east of him, and are to be seen in the evening, and those on the right in the morning. In the present case, Uranus, Saturn, Jupiter, and Mercury are evening stars, and Mars and Venus can only be seen in the morning. Jupiter is in an aspect nearly *quartile*, or three signs distant from the sun, and Uranus is nearly in the same aspect. Saturn is much nearer the sun, and Mercury is not far from the period of its greatest *eastern* elongation. Mars is not far from being in a quartile aspect *west* of the sun, and Venus is near the same point of the heavens, approaching to the period of its greatest *western* elongation, and consequently will be seen

before sunrise as a beautiful morning star. Jupiter and Uranus, to the east of the sun, appear nearly directly opposite to Venus and Mars, which are to the west of the sun. The phase* of Venus is nearly that of a half moon, and Mercury is somewhat gibbous, approaching to a half-moon phase. If, now, we turn the machine by the winch till the index of the earth point at the 8th of August, 1845, we shall find the planets in the following positions: Mars and Saturn are nearly in opposition to the sun; Venus and Mercury are evening stars, at no great distance from each other, and Jupiter is a morning star. In like manner, if we turn the machine till the index point to any future months, or even succeeding years, the various aspects and positions of the planets may be plainly perceived. When the planets are moved by the winch in this machine, we see them all *at once* in motion around the sun, with the same respective velocities and periods of revolution which they have in the heavens. As the planets are represented in the preceding positions, Mercury, Jupiter, and Mars are evening stars, and Venus, Saturn, and Uranus morning stars, if we suppose the earth placed in a line with our eye and the sun.

2. By this instrument, the truth of the Copernican or solar system is clearly represented. When the planets are in motion, we perceive the planets Venus and Mercury to pass both before and behind the sun, and to have two conjunctions. We observe Mercury to be never more than a certain angular distance from the sun as viewed from the earth, namely, 27°, and Venus 47°. We perceive that the superior planets, particularly Mars, will be sometimes much nearer to the earth than at others, and therefore must apppear larger at one time than at another, as they actually appear in the heavens. We see that the planets cannot appear from the earth to move with uniform velocity; for when nearest they appear to move faster, and slower when most remote. We likewise observe that the planets appear from the earth to move sometimes *direct*, or from west to east; then become retrograde, or from east to west, and between both to be *stationary;* all which particulars exactly correspond with celestial observations. For illustrating these particulars, there is a simple apparatus, represented by fig. 95, which consists of a hollow wire with a slit at top, which is placed over the arm of Mercury or Venus at *E*. The arm *D G* represents a ray of light coming from

Fig. 95.




the planet at *D* to the earth at *F*. The planets being then in motion, the planet *D*, as seen in the heavens from the earth at *F*, will undergo the several changes of position which we have described above, sometimes appearing to go backward, and at other times forward. The wire prop, now supposed to be placed over Mercury at *E*, may likewise be placed over any of the other planets, particularly Mars, and similar phenomena will be exhibited.

This machine may likewise be used to exhibit the falsity of the Ptolemaic system, which places the earth in the centre, and supposes the sun and all the planets to revolve around it. For this purpose, the ball representing the Sun is removed, and placed on the wire or pillar which supports the Earth, and the ball representing the Earth is placed in the centre. It will then be observed that the planets Mercury and Venus, being both within the orbit of the sun, cannot at any time be seen to go behind it, whereas in the heavens we as often see them go behind as before the sun. Again, it shows that as the planets move in circular orbits about the central earth, they ought at all times to appear of the same magnitude, while, on the contrary, we observe their apparent magnitudes in the heavens to be very variable, Mars, for example, appearing sometimes nearly as large as Jupiter, and at other times only like a small fixed star. Again, it is here shown that the planets may be seen at all distances from the sun; for example, when the sun is setting, Mercury and Venus, according to this arrangement, might be seen, not only in the south, but even in the eastern quarter of the heavens: a phenomenon which was never yet observed in any age, Mercury never appearing beyond 27° of the sun, nor Venus beyond 48°. In short, according to the system thus represented, it is seen that the motions of the planets should all be regular, and uniformly the same in every part of their orbits, and that they should all move the same way, namely, from west to east; whereas in the heavens they are seen to move with variable velocities, sometimes appearing stationary, and sometimes moving

* The balls which represent the different planets on this machine have their hemispheres painted black, with the white side turned directly to the sun, so that if the eye be placed in a line with the earth and the planet, particularly Mercury and Venus, its phase in the heavens at that time, as viewed with a telescope, may be distinctly perceived.

from east to west, and from west to east: all which circumstances plainly prove that the Ptolemaic cannot be the true system of the universe.

A planetarium such as that now described might be constructed with brass wheel-work for about five guineas. The brass wheel-work of one which I long since constructed cost about three guineas, and the other parts of the apparatus about two guineas more. The following are the prices of some instruments of this kind as made by Messrs. Jones, 30 Lower Holborn, London: "An orrery, showing the motions of the Earth, Moon, and inferior planets, Mercury, and Venus, by wheel-work, the board on which the instrument moves being 13 inches diameter, £4. 14*s*. 6*d*. A planetarium, showing the motions of all the primary planets by wheel-work with 1½ inch or three inch papered globes, according to the wheel-work and the neatness of the stands, from £7 17*s*. 6*d*. to £10 10*s*. Ditto, with wheel-work to show the parallelism of the Earth's axis, the motions of the Moon, her phases, &c., £18 18*s*. Ditto, with wheel-work to show the Earth's diurnal motion, on a brass stand in mahogany case, £22 1*s*. A small *tellurian*, showing the motion of the Earth and Moon, &c., £1 8*s*."

### HENDERSON'S PLANETARIUM.

The following is a description of the most complete and accurate planetarium I have yet seen. The calculations occupied more than eight months. For this article I am indebted to my learned and ingenious friend, Dr. Henderson, F.R.A.S., who is known to many of my readers by his excellent astronomical writings.

Fig. 96.

Section of the wheel-work of a planetarium for showing with the utmost degree of accuracy the mean tropical revolutions of the planets round the sun, calculated by E. Henderson, L.L.D., &c.

In the section the dark horizontal lines represent the wheel-work of the planetarium, and the annexed numerals the numbers of teeth in the given wheel. The machine has three axes or arbours, indicated by the letters *A B C*. Axis "*C*," the "yearly axis," is assumed to make one revolution in 365,242,236 days, or in 365 days 5h 48m 49.19s, and is furnished with wheels, 17, 44, 54, 36, 140, 96, 127, 86, which wheels are all firmly riveted to said axis, and consequently they turn round with it in the same time. Axis "*B*" is a fixture; it consists of a steel rod, on which a system of pairs of wheels revolve; thus wheels 40 and 77 are made fast together by being riveted on the same collet, represented by the thick, dark space between them, as also of the rest: the several wheels on this axis may be written down thus: [illegible], [illegible], [illegible], [illegible], 30, [illegible], [illegible], [illegible], 96, [illegible], [illegible]. On axis *A*, a system of wheels, furnished with tubes, revolve, and these tubes carry horizontal arms, supporting perpendicular stems with the planets. The wheels on this axis are 173, [illegible], 111, 119, [illegible], [illegible], 83, 239, 96, 128, 72. From the following short description, the nature of their several actions will, it is presumed, be readily understood, viz.

MERCURY'S PERIOD. On the axis "*C*" at the bottom is wheel 86, which turns round in 365 days 5h 48m 49.19s. This wheel impels a small wheel of 22 teeth, to which is made fast wheel 67, both revolving together at the foot of axis *B*; wheel 67 drives a wheel of 72 once round in the period of 87 days 23h 14m 36.1s: this last-mentioned wheel has a long tube, which turns on the steel axis *A*, and carries a horizontal arm with the planet Mercury round the sun in the time above noted.

VENUS'S PERIOD. On axis "*C*" is wheel 127, which drives wheel 47, to which is riveted a wheel of 77 teeth, which impels a wheel of 128 teeth on axis *A*, and causes it to make a revolution in 224 days 16h 41m 31.1s, and is furnished with a tube, which revolves over that of Mercury, and ascends through the cover of the machine, and bears an arm on which is placed a small ball representing this planet in the time stated.

THE EARTH'S PERIOD. The motion of the Earth round the Sun is simply effected as follows: the assumed value of axis "*C*" the "yearly axis," is 365 days 5h 48m 49.19s; hence a system of wheels having the same number of

teeth, or, at all events, the first mover and last wheel impelled, must be equal in their numbers of teeth. In this machine three wheels are employed, thus: a wheel having 96 teeth is made fast to the yearly axis *C*, and of course moves round with it in a mean solar year, as above noted; this wheel impels another wheel of 96 teeth on axis *B*, and this, in its turn, drives a third wheel of 96 teeth on axis *A*, and is furnished with a long tube which revolves over that of Venus, and ascends above the cover-plate of the machine, and bears a horizontal arm which supports a small terrestrial globe, which revolves by virtue of said wheels once round the sun in 365 days $5^h$ $48^m$ $49.19^s$.

**MARS'S PERIOD.** The revolution of this planet is effected as follows: a wheel of 140 teeth is made fast to the yearly axis *C*, and drives on axis *B* a wheel of 65 teeth, to which is fixed a wheel of 59 teeth, which impels a large wheel of 239 teeth on axis *A* once round the sun in 686 days $22^h$ $18^m$ $33.6^s$: this last mentioned wheel is also furnished with a tube which revolves over that of the earth, and carries a horizontal arm bearing the ball representing Mars, and causes it to complete a revolution round the sun in the period named.

**THE ASTEROIDS.**

**VESTA'S PERIOD.** The period of of Vesta is accomplished thus, viz.: on the yearly axis *C* is made fast a wheel of 36 teeth, which drives a wheel of 65 teeth, on axis *B*, to which is fixed a wheel of 41 teeth, which impels a wheel of 83 teeth on axis *A* once round in 1336 days $0^h$ $21^m$ $19.8^s$; the tube of which last wheel ascends on that of Mars, and, like the rest, bears an arm supporting a ball representing this planet.

**JUNO'S PERIOD.** For the revolution of Juno, the yearly axis *C* is furnished with a wheel of 54 teeth, which impels a wheel of 50 teeth on axis *B*, to which is made fast a wheel of 27 teeth, which turns a wheel of 127 teeth on axis *A* once round in 1590 days $17^h$ $35^m$ $2.7^s$, and the tube of which ascends on that of Vesta, and supports a horizontal arm which carries a small ball representing this planet in the period named.

**CERES'S PERIOD.** The revolution of Ceres is derived from the period of Juno, because wheel-work taken from the unit of a solar year was not sufficiently accurate for the purpose, therefore on Juno's wheel of 127 teeth is fixed a wheel of 123 teeth, which drives a thick little bevel sort of wheel of 30 teeth on axis *B*: the reason of this small wheel being bevelled is to allow its teeth to suit both wheels $\frac{123}{130}$; wheel 30 drives wheel 130 on axis *A* once round in 1681 days $6^h$ $17^m$ $22.4^s$, and the tube of wheel 130 turns on the tube of Juno, and ascends in a similar manner with the rest, and carries a horizontal arm supporting a small ball representing this planet, and is caused to revolve round the Sun in the above-mentioned period (the period of Ceres to that of Juno is as 130 is to 123: hence the wheels used.)

**PALLAS'S PERIOD.** The period of Pallas could not be derived from the solar year with sufficient accuracy, and recourse was had to an engrafted fraction on the period of Ceres, thus: on wheel 130 of Ceres is made fast a wheel of 122 teeth, which drives a wheel of 81 teeth on axis *B*, to which is fixed a wheel 79, which impels a wheel of 119 teeth on axis *A*, and is furnished with a tube which ascends, and turns on that of Ceres, and supports a horizontal arm, which bears a small ball representing this planet, which by virtue of the above train of wheels is caused to complete a revolution round the Sun in 1681 days $10^h$ $28^m$ $25.1^s$.

**JUPITER'S PERIOD.** The motion of this planet is derived from the period of a solar year, from the "yearly axis," thus: on this axis is made fast a wheel of 44 teeth, which turns a wheel of 94 teeth on axis *B*, to which is riveted a small wheel of 20 teeth, which impels a wheel on axis *A* having 111 teeth, which is furnished with an ascending tube which revolves over that of Pallas, and bears a horizontal arm which supports a ball representing this planet, which by the said train of wheels is caused to revolve round the Sun in 4330 days $14^h$ $39^m$ $35.7^s$.

**SATURN'S PERIOD.** The periodic revolution of Saturn is also taken from the solar year, viz., a small wheel of 17 teeth is fixed to the "yearly axis" near its top, and drives a wheel of 129 teeth on axis *B*, to which is made fast a wheel of 49 teeth, which turns a

wheel of 190 teeth on axis $A$, whose tube ascends and revolves on that of Jupiter's tube, and supports an arm, having a ball representing Saturn and its rings, and which by the train of wheels is caused to perform a revolution round the sun in the period of 10,746 days $19^h$ $16^m$ $50.9^s$.

**URANUS'S PERIOD.** The revolution of this planet could not be attained with sufficient accuracy from the period of a solar year: the period is engrafted on that of Saturn's, thus: a wheel of 117 teeth is made fast to wheel 190 of Saturn, and consequently revolves in Saturn's period. This wheel of 117 teeth drives a wheel on axis $B$ having 77 teeth, to which is fixed a wheel of 40 teeth, which turns on axis $A$ a large wheel of 173 teeth, whose tube ascends and revolves over that of Saturn, and carries a horizontal arm which supports a ball representing this planet, which is caused to complete its revolution by such a train of wheels in the period of 30,589 days $8^h$ $26^m$ $58.4^s$. Such is a brief description of the motions of this comprehensive and very accurate machine.

The axis $A$, on which the planet tubular wheels revolve, performs a rotation in 25 days 10 hours, by virtue of the following train of wheels, $\frac{61}{14}+\frac{70}{12}$ of 24 hours, that is, a pinion of 14 is assumed to revolve in 24 hours, and to drive a wheel of 61 teeth, to which is fixed a pinion of 12, which turns the wheel 70 in the period noted; to this wheel-axis it is made fast, and by revolving with it exhibits the Sun's rotation.

**DIURNAL HAND.** The machine is turned by a handle or winch, which is assumed to turn round in 24 hours, and from this rotation of 24 hours a train of wheel-work is required to cause the "yearly axis" $C$ to turn once round in 365 days $5^h$ $48^m$ $49.19^s$, which is effected in the following manner, viz.: the train found by the process of the reduction of continuous fractions is $\frac{61}{14}+\frac{144}{18}+\frac{241}{23}$, that is, in the train for turning the Sun, the same pinion 14 turns the same wheel 61, and turns a pinion of 18 leaves, to which is fixed a wheel of 144 teeth, having a pinion of 23 leaves, which impels a large wheel of 241 teeth once round in 365.242236 days, or 365 days $5^h$ $48^m$ $49.19^s$. The last-mentioned wheel of 241 teeth is made fast to the under part of the "yearly axis" $C$ at $D$, the handle having a pinion of 14 leaves therefor, and, transmitting its motion through the above train, causes the yearly axis to revolve in the same period.

**REGISTRATING DATES.** The planetarium is also furnished with a system of wheels for registrating dates for either 10,000 years past or to come. The arrangement is not shown in the engraving, (to prevent confusion,) but it might be shortly described thus: near the top of the yearly axis is a hooked piece, $e$, which causes the tooth of a wheel of 100 teeth to start forward yearly; consequently, 100 starts of said wheel will cause it to revolve in 100 solar years; and it has a hand, which points on a dial on the cover of the machine the years: thus, for the present year, this hand will be over the number 45. This last-named wheel of 100 teeth has a pin, which causes a tooth of another wheel of 100 teeth to start once in 100 years; hence this last wheel will complete one revolution in 10,000 years; and it is for this purpose the former index or hand moves over a number yearly. The second index will pass over a number every 100 years; for the present year, the second-hand or index will be over the number 18, and will continue over it until the first index moves forward to 99; then both indexes will move at one time, viz., the first index to $O$ $O$ on the first concentric circle of the dial, and the second index to 19, denoting the year 1900, and so of the rest. By the ecliptic being divided in a series of four spirals, the machine makes a distinction between common and leap years, and indicates the common year as containing 365 days, and the leap year 366 days, by taking in a day in February every fourth year; thus, for any given period for 10,000 years past or to come, the various situations and aspects of the planets may be ascertained by operating with this machine, and this for thousands of years without producing a sensible error either in space or time. This planetarium wheel-work is inclosed in an elegant mahogany box of twelve sides; is about five feet in diameter by ten inches in depth. At each of the twelve angles, or sides, small brass pillars rise, and support a large ecliptic circle, on which are engraven the signs, degrees, and mi-

nutes of the ecliptic, the days of the month, &c. This mahogany box with the wheel-work is supported by a tripod stand three feet in height, and motion is communicated to the several balls representing the planets by turning the handle as before described. A planetarium of this complicated sort costs sixty guineas.

The following is a tabular view of the wheel-work, periods, &c.

| Planets' names. | Wheel-work. | Tropical periods produced by the wheel-work. | True mean tropical periods of the planets. |
|---|---|---|---|
| | | da. ho. m. s. | da. ho. m. s. |
| Mercury | . . . . . . . $\frac{22}{85}+\frac{67}{27}$ of a year | 87. 23. 14. 36. 1 | 87. 23. 14. 36 |
| Venus | . . . . . . . $\frac{47}{127}+\frac{128}{77}$ " | 224. 16. 41. 31.1 | 224. 16. 41. 36 |
| The Earth | Prime mover 96 + 96 + 96 " | 365. 5. 48. 49.19 | 365. 5. 48. 49 |
| Mars | . . . . . . . $\frac{65}{140}+\frac{239}{59}$ " | 686. 22. 18. 33.6 | 686. 22. 18. 34 |
| Vesta | . . . . . . . $\frac{65}{36}+\frac{83}{41}$ " | 1335. 0. 21. 19.8 | 1335. 0. 21. 20 |
| Juno | . . . . . . . $\frac{50}{54}+\frac{127}{27}$ " | 1590. 17. 36. 2.7 | 1590. 17. 35. 1 |
| Ceres | . . . . . . . $\frac{130}{123}+30$ of Juno | 1681. 6. 17. 22.4 | 1681. 6. 17. 29 |
| Pallas | . . . . . . . $\frac{81}{122}+\frac{119}{79}$ of Ceres | 1681. 10. 28. 25.1 | 1681. 10. 28. 42 |
| Jupiter | . . . . . . . $\frac{94}{44}+\frac{111}{20}$ of a year | 4330. 14. 39. 35.7 | 4330. 14. 39. 32 |
| Saturn | . . . . . . . $\frac{129}{17}+\frac{190}{49}$ " | 10746. 19. 16. 50.9 | 10746. 19. 16. 52 |
| Uranus | . . . . . . . $\frac{77}{117}+\frac{173}{40}$ of Saturn | 30589. 8. 26. 58.4 | 30589. 8. 26. 39 |
| The Sun's rotation | $\frac{61}{41}+\frac{70}{12}$ of 24 hrs. | 25. 10. 0. 0. | 25. 10. 0. 1 |
| The tropical period of the Earth round the Sun . . | $\frac{61}{14}+\frac{144}{18}+\frac{241}{23}$ " | 365. 5. 48. 49.19 | 365. 5. 48. 49 |

In the month of October last year, Dr. Henderson made a series of calculations for a new planetarium for the use of schools. It shows with considerable accuracy for 700 days the mean tropical revolutions of the planets round the sun. The machine consists of a system of brass wheels peculiarly arranged, and is inclosed in a circular case three feet in diameter, the top of which has the signs and degrees of the ecliptic laid down on it, as also the days of the months, &c. This planetarium costs only 45s., or, on a tripod stand, table-high, 55s.: the machine is put in motion by a handle on the outside. To the teachers and others connected with education, this planetarium must be of great importance, for without a proper elucidation of the principles of astronomy, that of Geography must be but confusedly understood. This planetarium is at present made by Mr. Dollond, 9 White Conduit Grove, Islington, London.

The *Tellurian* is a small instrument which should be used in connexion with the planetarium formerly described. This instrument is intended to show the annual motion of the earth, and the revolution of the moon around it. It also illustrates the moon's phases and the motion of her nodes, the inclination of the Earth's axis, the causes of eclipses, the variety of seams, and other phenomena. It consists of about eight wheels, pinions, and circles. A small instrument of this description may be purchased for about £1 8s., as stated on page 183.

### ON THE VARIOUS OPINIONS WHICH WERE ORIGINALLY FORMED OF SATURN'S RING.

The striking and singular phenomenon connected with the planet Saturn, though now ascertained beyond dispute to be a ring or rings surrounding its body at a certain distance, was a subject of great mystery, and gave rise to numerous conjectures and controversies for a considerable time after the invention of the telescope by which it was discovered. Though it was first discovered in the year 1610, it was nearly 50 years afterward before its true form and nature were

determined. Galileo was the first who discovered any thing uncommon connected with Saturn: through his telescope he thought he saw that planet appear like two smaller globes on each side of a larger one; and after viewing the planet in this form for two years, he was surprised to see it becoming quite round, without its adjoining globes, and some time afterward to appear in the triple form. This appearance is represented in fig. 1 of the following engraving. In the year 1614, Scheiner, a German astronomer, published a representation of Saturn, in which this planet is exhibited as a large central globe, with two smaller bodies, one on each side, partly of a conical form, attached to the planet, and forming a part of it, as shown fig. 2. In the years 1640 and 1643, Ricciolus, an Italian mathematician and astronomer, imagined he saw Saturn as represented in fig. 3, consisting of a central globe, and two conical-shaped bodies completely detached from it, and published an account of it corresponding to this view. Hevelius, the celebrated astronomer of Dantzig, author of the *Selenographia* and other works, made many observations on this planet about the years 1643, 1649, and 1650, in which he appears to have obtained different views of the planet and its appendages, gradually approximating to the truth, but still incorrect. These views are represented in figures 4, 5, 6, and 7. Fig. 4 nearly resembles two hemispheres, one on each side of the globe of Saturn. The other figures very nearly resemble the extreme parts of the ring as seen through a good telescope, but he still seems to have considered them as detached from each other as well as from Saturn. Figures 8 and 9 are views given by Ricciolus at a period posterior to that in which he supposed Saturn and his appendages in the form delineated in fig. 3. In these last delineations the planet was supposed to be inclosed in an elliptical ring, but this ring was supposed to be *fixed* to its two opposite sides.

Fig. 97.

Fig. 10 is a representation by Eustachius Divini, a celebrated Italian optician at Bologna. The shades represented on Saturn and the elliptical curve are incorrect, as this planet presents no such shadowy form. The general appearance here presented is not much unlike that which the ring of Saturn exhibits, excepting that at the upper side of the ring should appear covering a portion of the orb of Saturn; but Divini seems to have conceived that the curve on each side was attached to the body of Saturn; for when Huygens published his discovery of the ring of Saturn in 1659, Divini contested its truth, because he could not perceive the ring through his own telescopes; and he wrote a treatise on the subject in opposition to Huygens in 1660, entitled "Brevis Annotatio in Systema Saturnium." Huygens immediately replied to him, and Divini wrote a rejoinder in 1661. Fig. 11 is the representation given by Francis Fontana, a Neapolitan astronomer. This figure represents Saturn as having two crescents, one on each side, attached to its body, with intervals between the planet and the crescents. Fig. 12 is a view delineated by Gassendus, a celebrated French philosopher. It represents the planet as a large ellipsoid, having a large circular opening near each end, and if this representation were the true one, each opening would be at least 30,000 miles in diameter. Fig. 13, which is perhaps the most singular of the whole, is said to be one of the views of this planet given by Ricciolus. It represents two globes, each of which, in the proportion they here bear to Saturn, must be more than 30,000 miles in diameter. These globes were conceived as being attached to the body of Saturn by curves or bands, each of which, in the proportion represented, must have been at least 7000 miles in breadth, and nearly 40,000 miles long. This would have exhibited the planet Saturn as a still more singular body than what we have found it to be; but no such construction of a planet has yet been found in the universe, nor is it probable that such a form of a planetary body exists.

It is remarkable that only two general opinions should have been formed respecting the construction of Saturn, as appears from these representations: either that this planet was composed of three distinct parts, separate from each other, or that the appendage on each side was *fixed* to the body of the planet. The idea of a ring surrounding the body of the planet at a certain distance from every part of it seems never to have been thought of till the celebrated Huygens, in 1655, 1656, and 1657, by numerous observations made on this

planet, completely demonstrated that it is surrounded by a solid and permanent ring, which never changes its situation, and, without touching the body of the planet, accompanies it in its revolution around the sun. As the cause of all the erroneous opinions above stated was owing to the imperfection of the telescopes which were then in use, and their deficiency in magnifying power, this ingenious astronomer set himself to work in order to improve telescopes for celestial observations. He improved the art of grinding and polishing object-glasses, which he finished with his own hands, and produced lenses of a more correct figure, and of a longer focal distance, than what had previously been accomplished. He first constructed a telescope 12 feet long, and afterward one 23 feet long, which magnified about 95 times; whereas Galileo's best telescope magnified only about 33 times. He afterward constructed one 123 feet long, which magnified about 220 times. It was used without a tube, the object-glass being placed upon the top of a pole, and connected by a cord with the eyepiece. With such telescopes this ingenious artist and mathematician discovered the fourth satellite of Saturn, and demonstrated that the phenomenon which had been so egregiously misrepresented by preceding astronomers consisted of an immense ring surrounding the body, and completely detached from it. His numerous observations and reasonings on this subject were published in Latin in 1659, in a quarto volume of nearly 100 pages, entitled "*Systema Saturnium, sive de causis mirandorum Saturni Phenomenon, et Comite ejus Planeta Nova*," from which work the figures and some of the facts stated above have been extracted.

## ON THE SUPPOSED DIVISIONS OF THE EXTERIOR RING OF SATURN.

From the period in which Huygens lived till the time when Herschel applied his large telescopes to the heavens, few discoveries were made in relation to Saturn. Cassini, in 1671, discovered the fifth satellite of this planet; in 1672, the third; and the first and second in March, 1684. In 1675, Cassini saw the broad side of its ring bisected quite round by a dark elliptical line, of which the inner part appeared brighter than the outer. In 1722, Mr. Hadley, with his five-feet Newtonian reflector, observed the same phenomenon, and perceived that the dark line was stronger next the body, and fainter towards the upper edge of the ring. Within the ring he also discovered two belts across the disk of Saturn; but it does not appear that they had any idea that this dark line was empty space separating the ring into two parts. This discovery was reserved for the late Sir W. Herschel, who made numerous observations on this planet, and likewise ascertained that the ring performs a revolution round the planet in ten hours and thirty minutes.

Of late years, some observers have supposed that the exterior ring of Saturn is divided into several parts, or, in other words, that it consists of two or more concentric rings. The following are some of the observations on which this opinion is founded. They are chiefly extracted from Captain Kater's paper on this subject, which was read before the Astronomical Society of London.

The observations, we are told, were made in the years 1825 and 1826, and remained unpublished from a wish on the part of the observer to witness the appearances again. The planet Saturn has been much observed by Captain Kater for the purpose of trying the light, &c., for which the ring and satellites are good tests. The instruments which were employed in the present investigations were two Newtonian reflectors, one by Watson, of 40 inches focus and 6¼th aperture, and another by Dollond, of 68 inches focus and 6¾ths aperture. The first, under favourable circumstances, gave a most excellent image; the latter is a very good instrument. The following are extracts from the author's journal:

*Nov.* 25, 1825. The double ring beautifully defined, perfectly distinct all around, and the principal belts well seen. I tried many concave glasses, and found that the image was much sharper than with convex eyeglasses, and the light apparently much greater. Dollond, 259, the best power, 480, a single lens, very distinct. *Nov.* 30, the night very favourable, but not equal to the 25th. The exterior ring of Saturn is not so bright as the interior, and the interior is less bright close to the edge next the planet. The inner edge appears more yellow than the rest of the ring, and nearer in colour to the body of the planet. *Dec.* 17. The evening extremely fine. With Dollond I perceived the outer ring of Saturn to be darker than the inner, and the division of the ring all around with perfect distinctness; but with Watson I fancied that I saw *the outer ring separated by numerous dark divisions extremely close, one stronger than the rest, dividing the ring about equally.* This was seen with my most perfect single eyeglass power. A careful examination of some hours confirmed this opinion. *Jan.* 16 and 17, 1826. Captain Kater believed that he saw the divisions with the Dollond, but was not positive. Concave eyeglasses found to be superior to convex. *Feb.* 26, 1826. The division of the outer ring not seen with Dollond. On the 17th Dec., when the divi

sions were most distinctly seen, Captain Kater made a drawing of the appearance of Saturn and his rings. The phenomena were witnessed by two other persons on the same evening, one of whom saw several divisions in the outer ring, while the other saw one middle division only; but the latter person was short-sighted, and unaccustomed to telescopic observations. It may be remarked, however, that these divisions were not seen on other evenings, which yet were considered very favourable for distinct vision.

It is said that the same appearances were seen by Mr. Short, but the original record of his observations cannot be found. In Lalande's *Astronomy* (3d edition, article 3351) it is said, "Cassini remarked that the breadth of the ring was divided into two equal parts by a dark line having the same curvature as the ring, and the *exterior* portion was the less light. Short *told* me that he observed still more singular phenomena with his large telescope of 12 feet. 'The breadth of the ansæ, or extremities of the ring, was, according to him, divided into two parts, an inner portion without any break in the illumination, and an outer divided by several lines concentric with the circumference, which would lead to a belief *that there are several rings in the same plane*." De Lambre and Birt severally state that Short saw the outer ring divided, probably on the authority of Lalande. In Brewster's *Ferguson's Astronomy*, vol. ii. p. 125, 2d edition, there is the following note on this subject: "Mr. Short assures us that with an excellent telescope he observed the surface of the ring divided by several dark concentric lines, which seem to indicate a number of rings proportional to the number of dark lines which he perceived."

In December, 1813, at Paris, Professor Quetelet saw the outer ring divided with the achromatic telescope of ten inches aperture, which was exhibited at the exposition. He mentioned this the following day to M. de la Place, who observed that "those, or even more divisions, were conformable to the system of the world." On the other hand, the division of the outer ring was not seen by Sir W. Herschel in 1792, nor by Sir J. Herschel in 1826, nor by Struve in the same year; and on several occasions when the atmospheric conditions were most favourable, it has not been seen by Captain Kater. It has been remarked by Sir W. Herschel, Struve, and others, that the exterior ring is much less brilliant than the interior; and it is asked, May not this want of light in the outer ring arise from its having a very dense atmosphere? and may not this atmosphere in certain states admit of the divisions of the exterior ring being seen, though, under other circumstances, they remain invisible? The above observations are said to have been confirmed by some recent observations by Decuppis at Rome, who announced, some years ago, that Saturn's outer ring is divided into two or three concentric rings.

Some of the observations stated above, were they perfectly correct, would lead to the conclusion that Saturn is encompassed with a number of rings concentric with and parallel to each other. But while such phenomena as described above are so seldom seen, even by the most powerful telescopes and the most accurate observers, a certain degree of doubt must still hang over the subject; and we must suspend our opinion on this point till future observations shall either confirm or render doubtful those to which we have referred. Should the Earl of Rosse's great telescope, when finished for observation, be found to perform according to the expectations now entertained, and in proportion to its size and quantity of light, we shall expect that our doubts will be resolved in regard to the supposed divisions of the ring of Saturn.

(907)

# APPENDIX.

## BRIEF DESCRIPTION OF THE EARL OF ROSSE'S TELESCOPE.

This telescope, the largest and most magnificent that ever was attempted, reflects the greatest honour on the genius, the inventive powers, and the scientific acquirements of its noble contriver, as well as on the elevated station in which he is placed. With rank and fortune, and every circumstance that usually unfit men for scientific pursuit, he has set a bright example to his compeers of the dignity and utility of philosophical studies and investigations, and of the aids they might render to the progress of science, were their wealth and pursuits directed in a proper channel.

Previously to his lordship's attempting the construction of his largest, or "Monster Telescope," he had constructed one with a speculum of three feet in diameter, which was considered one of the most accurate and powerful instruments that had ever been made, not excepting even Sir W. Herschel's forty feet reflector. In the account of this telescope published in the Philosophical Transactions for 1840, his lordship speaks of the possibility of a speculum of six feet in diameter being cast. At that time it was considered by some as little short of a chimera to attempt the construction of such a monstrous instrument; but the idea no sooner occurred to this ingenious and persevering nobleman than he determined to put it to the test, and the result has been attended with complete success. The materials of which this speculum is composed are *copper* and *tin*, united very nearly in their atomic proportions, namely, copper 126.4 parts, to tin 58.9 parts. This compound has a specific gravity of 8.8, and is found to preserve its lustre with more splendour, and to be more free from pores than any other. A foundry was constructed expressly for the purpose of casting the speculum. Its chimney, built from the ground, was 18 feet high, and 16½ square at the base, tapering to four at the top. At each of its sides, communicating with it by a flue, was sunk a furnace eight feet deep and 5½ square, with a circular opening four feet in diameter. About seven feet from the chimney was erected a large crane, with the necessary tackle for elevating and carrying the crucibles from the furnace to the mould, which was placed in a line with the chimney and crane, and had three iron baskets supported on pivots hung round it; and four feet further on was the annealing oven. The crucibles which contained the metal were each two feet in diameter, 2½ deep, and together weighed one ton and a half. They were of cast iron, and made to fit the baskets at the side of the mould. These baskets were hung on wooden uprights, or pivots; to one of these, on each side, was attached a lever, by depressing which it might be turned over, and the contents of the crucible poured into the mould. The bottom of the mould was made by binding together tightly layers of hoop iron, and turning the required shape on them edgewise. This mould conducted the heat away through the bottom, and cooled the metal towards the top in infinitely small layers, while the interstices, though close enough to prevent the metal from escaping, were sufficiently open to allow the air to penetrate. This bottom was six feet in diameter and 5½ inches thick, and was made perfectly horizontal by means of spirit levels, and was surrounded by a wooden frame. A wooden pattern, the exact size of the speculum, being placed on the iron, sand was well packed between it and the frame, and the pattern was removed. Each of the crucibles containing the melted metal was then placed in its basket, and every thing being ready for discharging their contents, they were at the same instant turned over, and the mould being filled, the metal in a short time safely set into the required figure. While it was red hot, and scarcely solid, the framework was removed, and an iron ring connected with a bar which passed through the oven being placed round it, it was drawn in by means of a capstan at the other side, on a railroad, when charcoal being lighted in the oven, and turf fires underneath it, all the openings were built up, and it was left for sixteen weeks to anneal. It was cast on the 13th of April, 1842, at 9 o'clock in the evening. The crucibles were ten hours heating in the furnaces before the metal was introduced, which in about ten hours more was sufficiently fluid to be poured. When the

oven was opened the speculum was found as perfect as when it entered it. It was then removed to the grinding machine, where it underwent that process, and afterward was polished, without any accident having occurred.

This speculum weighed *three tons*, and lost about one-eighth of an inch in grinding. Lord Rosse has since cast another speculum of the same diameter four tons in weight. He can now, with perfect confidence, undertake any casting, so great an improvement has the form of mould which he has invented proved. The speculum was placed on an equilibrium bed, composed of nine pieces, resting on points at their centres of gravity. The pieces were lined with pitch and felt before the speculum was placed on them. The speculum box is also lined with felt, and pitched: this prevents any sudden change of temperature affecting the speculum by means of the bad conducting power of the substances employed. A vessel of lime is kept in connexion with the speculum box to absorb the moisture, which otherwise might injure the mirror. The process of grinding was conducted under water, and the moving power employed was a steam-engine of three horse power. The polisher is connected with the machinery by means of a large ring of iron, which loosely encircles it; and instead of either the speculum or the polisher being stationary, both move with a regulated speed. The ring of the polisher, and therefore the polisher itself, has a transverse and a longitudinal motion; it makes 80 strokes in the minute, and $24\frac{1}{2}$ strokes backward and forward for every revolution of the mirror, and at the same time $1\frac{78}{100}$th strokes in the transverse direction. The extent of the latter is $\frac{27}{100}$ths of the diameter of the speculum. The substance made use of to wear down the surface was emery and water: a constant supply of these was kept between the grinder and the speculum. The grinder is made of cast iron, with grooves cut lengthwise, across, and circularly on its face. The polisher and speculum have a mutual action upon each other: in a few hours, by the help of the emery and water, they are both ground truly circular, whatever may have been their previous defects. The grinding is continued till the required form of surface is produced, and this is ascertained in the following manner: there is a high tower over the house in which the speculum is ground, on the top of which is fixed a pole, to which is attached the dial of a watch; there are trap-doors which open, and by means of a temporary eyepiece, allow the figure of the dial to be seen in the speculum brought to a slight polish. If the dots on the dial are not sufficiently well defined, the grinding is continued; but if they appear satisfactorily, the polishing is commenced. It required six weeks to grind it to a fair surface. The polisher was cut into grooves, to prevent the abraded matter from accumulating in some places more than in others; a thin layer of pitch was spread over it; it was smeared over with rouge and water, and a supply of it kept up till the machinery brought it to a fine black polish. The length of time employed for polishing the three feet speculum was six hours.*

This large telescope is now completed, or nearly so. The tube is 56 feet long, including the speculum box, and is made of deal one inch thick, hooped with iron. On the inside, at intervals of eight feet, there are rings of iron three inches in depth and one inch broad, for the purpose of strengthening the sides. The diameter of the tube is seven feet. It is fixed to mason-work in the ground by a large universal hinge, which allows it to turn in all directions. At 12 feet distance on each side a wall is built, 72 feet long, 48 high on the outer side, and 56 on the inner, the walls being 24 feet distant from each other, and lying exactly in the meridianal line. When directed to the south, the tube may be lowered till it becomes almost horizontal; but when pointed to the north, it only falls till it is parallel with the earth's axis, pointing then to the pole of the heavens. Its lateral movements take place only from wall to wall, and this commands a view for half an hour on each side of the meridian; that is, the whole of its motion from east to west is limited to 15 degrees. At present it is fitted up in a temporary way to be used as a transit instrument; but it is ultimately intended to connect with the tube-end galleries machinery which shall give an automaton movement, so that the telescope shall be used as an equatorial instrument. All the works connected with this instrument are of the strongest and safest kind; all the iron work was cast in his lordship's laboratory by men instructed by himself, and every part of the machinery was made under his own eye by the artisans in his own neighbourhood, and not a single accident worth mentioning happened during the whole proceeding.

The expense incurred by his lordship in the erection of this noble instrument was not less than *twelve thousand pounds!* besides the money expended in the construction of the telescope of three feet diameter. Sufficient

* The above description has been selected and abridged from a small volume entitled "The Monster Telescope, erected by the Earl of Rosse, Parsontown," and also from the "Illustrated London News" of September 9th, 1843. In the volume alluded to a more particular description will be found, accompanied with engravings.

time has not yet been afforded for making particular observations with this telescope; but from slight trials which have been made, even under unfavourable circumstances, it promises important results. Its great superiority over every telescope previously constructed consists in the great quantity of light it reflects, and the brilliancy with which it exhibits objects, even when high powers are applied. It has a reflecting surface of 4071 square inches, while that of Herschel's 40 feet telescope had only 1811 square inches on its polished surface, so that the quantity of light reflected from the speculum is considerably more than double that of Herschel's largest reflector. This instrument has already exceeded his lordship's expectations. Many appearances before invisible in the Moon have been perceived, and there is every reason to expect that new discoveries will be made by it in the *Nebulæ*, double and triple stars, and other celestial objects. The following is an extract of a communication from Sir James South on this subject, addressed to the editor of the "*Times*;" "The leviathan telescope on which the Earl of Rosse has been toiling upward of two years, although not absolutely finished, was on Wednesday last directed to the sidereal heavens. The letter which I have this morning received from its noble maker, in his usual unassuming style, merely states that the metal, only just polished, was of a pretty good figure, and that with a power of 500 the nebula known as No. 2 of Messier's catalogue was even more magnificent than the nebula No. 13 of Messier, when seen with his lordship's telescope of three feet diameter and 27 feet focus. Cloudy weather prevented him from turning the leviathan on any other nebulus object. Thus, then, we have all danger of the metal breaking before it could be polished overcome. Little more, however, will be done with it for some time, as the earl is on the eve of quitting Ireland for England to resign his post at York as president of the British Association. I look forward with intense anxiety to witness its first severe trial, when all its various appointments shall be completed, in the confidence that those who may then be present will see with it what man has never seen before. The diameter of the large metal is six feet, and its focus 54 feet; yet the immense mass is manageable by one man. Compared with it, the working telescopes of Sir William Herschel, which in his hands conferred on astronomy such inestimable service, and on himself astronomical immortality, were but playthings."

The following is a more recent account of observations made by this telescope, chiefly extracted from Sir James South's description, inserted in the *Times* of April 16th, 1845, and the "*Illustrated London News*" of April 19:

"The night of the 5th of March, 1845, was the finest I ever saw in Ireland. Many nebulæ were observed by Lord Rosse, Dr. Robinson, and myself. Most of them were, for the first time since their creation, seen by us as groups or clusters of stars; while some, at least to my eyes; showed no such resolution. Never, however, in my life did I see such glorious sidereal pictures as this instrument afforded us. Most of the nebulæ we saw I certainly have observed with my own achromatic; but although that instrument, as far as relates to magnifying power, is probably inferior to no one in existence, yet to compare these nebulæ, as seen with it and the six-feet telescope, is like comparing, as seen with the naked eye, the dinginess of the planet Saturn to the brilliancy of Venus. The most popularly-known nebulæ observed this night were the ring nebulæ in the *Canes Venatici*, or the 51st of Messier's catalogue, which was resolved into stars with a magnifying power of 548, and the 94th of Messier, which is in the same constellation, and which was resolved into a large globular cluster of stars, not much unlike the well-known cluster in Hercules, called also the 13th of Messier." Perfection of figure, however, of a telescope must be tested, not by nebulæ, but by its performance on a star of the first magnitude. If it will, under high power, show the star round and free from optical appendages, we may safely take it for granted it will not only show nebulæ well, but any other celestial object as it ought. To determine this point, the telescope was directed to *Regulus* with the entire aperture, and a power of 800, and "I saw," says Sir James, "with inexpressible delight, the star free from wings, tails, or optical appendages; not indeed, like a planetary disk, as in my large achromatic, but a round image resembling voltaic light, between charcoal points; and so little aberration had this brilliant image, that I could have measured its distance from, and position with any of the stars in the field with a spider's-line micrometer, and a power of 1000, without the slightest difficulty; for not only was the large star round, but the telescope, although in the open air, and the wind blowing rather fresh, was as steady as a rock."

"On subsequent nights, observations of other nebulæ, amounting to some thirty or more, removed most of them from the list of nebulæ, where they had long figured, to that of clusters; while some of these latter, more especially the 5th of Messier, exhibited a sidereal picture in the telescope such as man before had never seen, and which for its magnificence baffles all description. Several double stars were seen with various apertures of

the telescope, and with powers between 360 and 800; and as the earl had before told us we should—before the speculum was inserted in the tube, in consequence of his having been obliged to quit the superintendence of the polishing at the most critical part of the process—we found that a ring about six inches broad, reckoning from the circumference of the speculum, was not perfectly polished, and to *that* the little irradiation seen about Regulus was unquestionably referrible. The only double stars of the first class which the weather permitted us to examine with it were Xi Ursæ Majoris, and Gamma Virginis, which I could have measured with the greatest confidence. D'Arrest's comet we observed on the 12th of March, with a power of 400, but nothing worthy of notice was detected. Of the Moon, a few words must suffice. Its appearance in my large achromatic of 12 inches aperture is known to hundreds of readers; let them then imagine that with it they look *at* the moon, while with Lord Rosse's six-feet they look *into it*, and they will not form a very erroneous opinion of the performance of the leviathan. On the 15th of March, when the moon was seven days old, I never saw her unilluminated disk so beautifully, nor her mountains so temptingly measurable. On my first looking into the telescope, a star of about the seventh magnitude was some minutes of a degree from the moon's dark limb, and its occultation by the moon appeared inevitable. The star, however, instead of disappearing the moment the moon's edge came in contact with it, apparently glided on the moon's dark face, as if it had been seen through a transparent moon, or as if the star were between me and the moon. It remained on the moon's disk nearly two seconds of time, and then disappeared. I have seen this apparent projection of a star on the moon's face several times, but from the great brilliancy of the star, this was the most beautiful I ever saw. The cause of this phenomenon is involved in impenetrable mystery.

The following is a representation of the great Rosse telescope, along with part of the buildings with which it is connected. In the interior face of the eastern wall a very strong iron arc of about 43 feet radius is firmly fixed, provided with adjustments, whereby its surface facing the telescope may be set very accurately in the plane of the meridian. On this bar lines are drawn, the interval between any adjoining two of which corresponds to one minute of time on the equator. The tube and speculum, including the bed on which the speculum rests, weigh about 15 tons. The telescope rests on a universal joint, placed on masonry about six feet below the ground, and is elevated or depressed by a chain and windlass; and although it weighs about 15 tons, the instrument is raised by two men with great facility: of course, it is counterpoised in every direction. The observer, when at work, stands in one of four galleries, the three highest of which are drawn out from the western wall, while the fourth or lowest has for its base an elevating platform, along the horizontal surface of which a gallery slides from wall to wall by a machinery within the observer's reach, but which a child may work. When the telescope is about half an hour east of the meridian, the galleries, hanging over the gap between the walls, present to a spectator below an appearance somewhat dangerous; yet the observer, with common prudence, is as safe as on the ground, and each of the galleries can be drawn from the wall to the telescope's side so readily, that the observer needs no one else to move it for him.

The following figure (98) represents only the upper part of the tube of the telescope, at which the observer stands when making his observations. The telescope is at present of the Newtonian construction, and, consequently, the observer looks into the side of the tube at the upper end of the telescope; but it is proposed to throw aside the plane speculum, and to adapt it to the *front view*,

Fig. 98.

on the plan already described, (see pp. 111, 113, &c.,) so that the observer will sit or stand with his back towards the object, and his face looking down upon the speculum; and in this position he will sometimes be elevated between 50 and 60 feet above the ground. As yet, the telescope has no equatorial motion, but it very shortly will; and at no very distant day, clockwork will be connected with it, when the observer will, while observing, be almost as comfortable as if he were reading at a desk by his fireside.

The following figure (99) shows a section of the machinery connected with this telescope. It exhibits a view of the inside of the eastern wall, with all the machinery as seen in section. *A* is the mason work on the ground; *B*, the universal joint, which allows the tube to turn in all directions; *C*, the speculum in its tube; *D*, the box; *E*, the eyepiece; *F*, the movable pulley; *G*, the fixed one; *H*, the chain from the side of the tube; *I*, the chain from the beam; *K*, the counterpoise; *L*, the lever; *M*, the chain connecting it with the tube; *Z*, the chain which passes from the tube to the windlass over a pulley on a trussbeam, which runs from *W* to the same situation on the opposite wall: the pulley is not seen; *X* is a railroad, on which the speculum is drawn either to or from its box: part is cut away, to show the counterpoise. The dotted line *a* represents the course of the weight *R* as the tube rises or falls: it is a segment of a circle, of which the chain *I* is the radius. The tube is moved from wall to wall by the ratchet and wheel at *R*; the wheel is turned by the handle *O*, and the ratchet is fixed to the circle on the wall. The ladders in front, as shown in the preceding sketch, enable the observer to follow the tube in its ascent to where the galleries on the side-wall commence. These side-galleries are three in number, and each can be moved from wall to wall by the observer after the tube, the motion of which he also accomplishes by means of the handle *O*.

I shall conclude the description of this wonderful instrument in the words of Sir James South:

"What will be the power of this telescope when it has its Le Mairean form" [that is, when it is fitted up with the front view,] "it is not easy to divine. What nebulæ will it resolve into stars? in what nebulæ will it not find stars? how many satellites of Saturn will it show us? how many will it indicate as appertaining to Uranus? how many nebulæ never yet seen by mortal eye will it present to us? what spots will it show us on the various planets? will it tell us what causes the variable brightness of many of the fixed stars? will it give us any information as to the constitution of the planetary nebulæ? will it exhibit to us any satellites encircling them? will it tell us why the satellites of Jupiter, which generally pass over Jupiter's face as disks nearly of white light, sometimes traverse it as black patches? will it add to our knowledge of the physical construction of nebulous stars? of that mysterious class of bodies which surround some stars, called, for want of a better name, 'photospheres?' will it show the annular nebulæ of Lyra merely as a brilliant luminous ring, or will it exhibit it as thousands of stars arranged in all the symmetry of an ellipse? will it enable us to comprehend the hitherto incomprehensible nature and origin of the light of the great nebulæ of Orion? will it give us, in easily appreciable quantity, the parallax of some of the fixed stars, or will it make sensible to us the parallax of the nebulæ themselves? finally, having presented to us original portraits of the moon and of the sidereal heavens, such as man has never dared even to anticipate, will it, by Daguerreotype aid, administer to us copies founded upon truth, and enable astronomers of future ages to compare the moon and heavens as they then may be with the moon and heavens as they were? Some of these questions will be answered affirmatively, others negatively, and that, too, very shortly; for the noble maker of the noblest instrument ever formed by man 'has cast his bread upon the waters, and will, with God's blessing, find it before many days.'"

Fig. 99.

## HINTS TO AMATEURS IN ASTRONOMY RESPECTING THE CONSTRUCTION OF TELESCOPES.

As there are many among the lower ranks of the community who have a desire to be possessed of a telescope which will show them some of the prominent features of celestial scenery, but who are unable to purchase a finished instrument at the prices usually charged by opticians, the following hints may perhaps be acceptable to those who are possessed of a mechanical genius.

The lenses of an achromatic telescope may be purchased separately from glass-grinders or opticians, and tubes of a cheap material may be prepared by the individual himself for receiving the glasses. The following are the prices at which achromatic object-glasses for astronomical telescopes are generally sold: Focal length 30 inches, diameter 2¼th inches, from 2 to 3½ guineas. Focal length 42 inches, diameter 2¾th inches, from 5 to 8 guineas. Focal length 42 inches, diameter 3¼th inches, from 12 to 20 guineas. Focal length 42 inches, diameter 3¾th inches, from 25 to 30 guineas. Eyepieces, from 10*s*. 6*d*. to 18 shillings. The smallest of these lenses, namely, that of 2¼th inches diameter, if truly achromatic, may be made to bear a power of from 80 to 100 times in clear weather for celestial objects, which will show Jupiter's moons and belts, Saturn's ring, and other celestial phenomena. The tubes may be made either of tin plates, *papier mache*, or wood. Wood, however, is rather a clumsy article, and it is sometimes liable to warp, yet excellent tubes have sometimes been made of it. Perhaps the cheapest and most convenient of all tubes, when properly made, are those formed of paper. In forming these, a wooden roller of the proper diameter should be procured, and paper of a proper size, along with bookbinder's paste. About three or four layers only of the paper should be pasted at one time, and, when sufficiently dry, it should be smoothed by rubbing it with a smooth stick or ruler; after which another series of layers should be pasted on, and allowed to dry as before, and so on till the tube has acquired a sufficient degree of strength and firmness. In this way I have, by means of a few old newspapers and similar materials, formed tubes as strong as if they had been made of wood. If several tubes be intended to slide into each other, the smallest tube should be made first, and it will serve as a roller for forming the tube into which it is to slide.

An achromatic object-glass of a shorter focal distance and a smaller diameter than any of those stated above, may be fitted up as a useful astronomical telescope when a better instrument cannot be procured. In the pawnbrokers' shops in London and other places, an old achromatic telescope, with an object-glass 20 inches focal distance and about 1½ inch diameter, may be purchased at a price varying from 15 to 20 shillings. By applying an astronomical eyepiece to such a lens, if a good one, it may bear a power for celestial objects of 50 or 60 times. If two plano-convex glasses three-fourths of an inch focal distance be placed with their convex sides near to each other, they will form an eyepiece which will produce a power on such an object-glass of above 50 times, which will show Jupiter's belts and satellites, Saturn's ring, the solar spots, and the mountains and cavities of the moon. I have an object-glass of this description which belonged to an old telescope, which cost me only 12 shillings, and with which I formally made some useful astronomical observations. It was afterwards used as the telescope of a small equatorial instrument, and with it I was enabled to perceive stars of the first and second magnitude, and the planets Venus, Jupiter, and Mars in *the daytime*.

But, should such a glass be still beyond the reach of the astronomical amateur, let him not altogether despair. He may purchase a single lens of three feet focal distance for about a couple of shillings, and by applying an eyeglass of one inch focus, which may be procured for a shilling, he will obtain a power of 36 times, which is a higher power than Galileo was able to apply to his best telescope; and consequently, with such an instrument, he will be enabled to perceive all the celestial objects which that celebrated astronomer first described, and which excited so much wonder at that period in the learned world; but, whatever kind of telescope may be used, it is essentially requisite that it be placed on a firm stand in all celestial observations; and any common mechanic can easily form such a stand at a trifling expense.

There is a certain optical illusion to which most persons are subject in the first use of telescopes, especially when applied to the celestial bodies, on which it may not be improper to make a remark. The illusion to which I allude is this, that they are apt to imagine the telescope does not magnify nearly so much as it really does; they are apt to complain of the small appearance which Jupiter and Saturn, for example, present when magnified 160 or 200 times. With such powers they are apt to imagine that these bodies do not appear so

large as the moon to the naked eye; yet it can be proved that Jupiter, when nearest the earth, viewed with such a power, appears about five times the diameter of the full moon, and 25 times larger in surface. This appears from the following calculation: Jupiter, when in opposition, or nearest the Earth, presents a diameter of 47″; the mean apparent diameter of the moon is about 31′; multiply the diameter of Jupiter by the magnifying power, 200, the product is 9400″, or 156′, or 2° 36′, which, divided by 31′, the moon's diameter, produces a quotient of 5, showing that this planet with such a power appears five times larger in diameter than the full moon to the naked eye, and consequently 25 times larger in surface. Were a power of only 50 times applied to Jupiter when nearest the earth, that planet would appear somewhat larger than the full moon; for 47″ multiplied by 50 gives 2350″, or 39′, which is 8′ more than the diameter of the moon; yet with such a power most persons would imagine that the planet does not appear one-third of the size of the full moon.

The principal mode by which a person may be experimentally convinced of the fallacy to which I allude is the following: At a time when Jupiter happens to be within a few degrees of the moon, let the planet be viewed through the telescope with the one eye, and the magnified image of the planet be brought into contact with the moon as seen with the other eye, the one eye looking at the moon, and the other viewing the magnified image of Jupiter through the telescope when brought into apparent contact with the moon; then it will be perceived that with a magnifying power of 50 the image of Jupiter will completely cover the moon as seen by the naked eye; and with a power of 200—when the moon is made to appear in the centre of the magnified image of the planet—it will be seen that Jupiter forms a large and broad circle around the moon, appearing at least five times greater than the diameter of the moon. This experiment may be varied as follows: Suppose a person to view the moon through a small telescope or opera-glass magnifying three times, he will be apt to imagine, at first sight, that she is not in the least magnified, but rather somewhat diminished; but let him bring the image as seen in the telescope in contact with the moon as seen with the naked eye, and he will plainly perceive the magnifying power by the size of the image. It may be difficult, in the first instance, to look at the same time at the magnified image and the real object, but a few trials will render it easy.



THE END.

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